WOOD ENERGY

SYMPOSIUM

SUR L'ÉNERGIE FORESTIÈRE

proceedings

WOOD ENERGY SYMPOSIUM PROCEEDINGS

OCTOBER 25-26, 1988

HUGH JOHN FLEMMING FORESTRY CENTRE

FREDERICTON, NEW BRUNSWICK

TABLE OF CONTENTS

PAGE

SUMMARY 1

TUESDAY, OCTOBER 25, 1988

OFFICIAL OPENING 2

SESSION "A". 3

RENEWABLE ENERGY: OFFSPRING OF OPEC?
A.E. Reinsch
Canadian Energy Research Institute 4

WOOD ENERGY IN PERSPECTIVE
Dr. D.L.P. Strange
Energy, Mines and Resources Canada 27

MAINE - TEN YEARS' DEVELOPMENT
Michael Cyr, Marketree 56

CURRENT ACTIVITY IN WOOD CHIP
COMBUSTION SYSTEMS IN THE ATLANTIC REGION
R.J. Brandon, P.E.I. Energy Corporation . . . 57

TOURS 73

EXHIBITS 75

WEDNESDAY, OCTOBER 26, 1988

SESSION "B" 76

SOCIO-ECONOMIC BENEFITS OF WOOD ENERGY
Dr. Colin B. High, Resource Systems Group . . 77

FOREST MANAGEMENT IMPLICATIONS OF WOOD ENERGY
Dr. Gordon Baskerville
University of New Brunswick 89

FINANCING OPTIONS
J.R. Dean, ADI Group 107

DESIGN AND OPERATION OF A 7.2 MW WOOD WASTE
CO-GENERATION PLANT - A CASE HISTORY
Peter Golobic, Paul Shervill
Ontario Ministry of Energy
William P. Ivey
Chapleau Cogeneration Limited 122

TABLE OF CONTENTS

PAGE

SESSION "C" 140

RESEARCH AND DEVELOPMENT IN WOOD ENERGY HARVESTING AND HANDLING
Dr. W.B. Stuart
Virginia Polytechnic Institute 141

EMISSION TEST RESULTS
K.T. Fraser
Research and Productivity Council 155

SMALL/MEDIUM FUELWOOD CHIPPING
Michael P. Folkema
Forest Engineering Research
Institute of Canada 168

FUEL HANDLING SYSTEMS FOR WOOD-HEATING PLANTS
J.F. Piercy, ADI Ltd. 188

APPENDIX A

LIST OF PARTICIPANTS 206

SUMMARY

The second in a series, the Wood Energy Symposium was held October 25 and 26, 1988 in the Hugh John Flemming Forestry Centre, Fredericton, N.B. It was sponsored by the Department of Natural Resources, Energy Branch.

The program was designed to provide direction for participants in their activities during the next decade. The speakers presented views based on considerable experience in their chosen disciplines. The field tours gave current illustrations of fuel processing and combustion systems while the exhibits were an added source of information.

The more than 120 participants, in the evaluation of the Symposium, were positive and objective and judged it to be successful. A number of their suggestions will be incorporated into future programs to meet both general and specific objectives. Geographically there were seven provinces and four states represented by industrial, governmental, academic and consulting people.

It is planned to hold the next Wood Energy Symposium in 1990 when initiatives of the present and following years will have established viability and replications can be considered.

E.T. OWENS
Chairman

ORGANIZING COMMITTEE

Darwin Curtis	Sydelle Grobe
Peggy Jones	Marie-Berthe Losier
Jim Richard	Laura Lee Williams
Lou Soucy	

WOOD ENERGY SYMPOSIUM

OFFICIAL OPENING

B.J. Walker, Deputy Minister
Department of Natural Resources and Energy

This is the second in a series of Wood Energy assemblies and I am extremely pleased to welcome participants to this review of developments of the past few years. An interesting and provocative program has been arranged which will give forecasts of energy into the 21st century.

It is specially gratifying to the organizers and the Department to have representatives from neighbouring states and provinces as well as overseas. The organizations which you represent have been pursuing a variety of energy options and we know from previous conferences that this will lead to excellent technology transfer.

While you are in Fredericton we hope that you will see much of what this capital city has to offer, beginning with this complex, the Hugh John Flemming Forestry Centre. The Department of Natural Resources and Energy is proud of its partnership in the Centre - and, having been the general manager during its initiation, it is of personal pride to recommend this location.

So with warm wishes for fruitful sharing of experience with colleagues from near and far, I declare this Wood Energy Symposium open.

SESSION "A"

Moderator - D.E. Barnett, Department of Natural Resources and Energy

1. RENEWABLE ENERGY: OFFSPRING OF OPEC?
   A.E. Reinsch, Canadian Energy Research Institute

2. WOOD ENERGY IN PERSPECTIVE
   Dr. D.L.P. Strange, Energy, Mines and Resources Canada

3. MAINE - TEN YEARS' DEVELOPMENT
   Michael Cyr, Marketree

4. CURRENT ACTIVITY IN WOOD CHIP COMBUSTION SYSTEMS IN THE ATLANTIC REGION
   R.J. Brandon, P.E.I. Energy Corporation

RENEWABLE ENERGY: OFFSPRING OF OPEC

Anthony E. Reinsch

Canadian Energy Research Institute

Good morning, ladies and gentlemen. On behalf of the Canadian Energy Research Institute, I would like to thank the symposium organizers for inviting me here today to address the outlook for the world oil market and the messages contained therein for the future of renewable energy.

While the subject of world oil markets and prices may seem somewhat out of keeping with the central conference theme, I feel the symposium organizers have shown considerable insight in scheduling a discussion of the future of world oil market developments at the outset of this series of meetings. As I hope to show through my comments to you today, the reality of oil in the world energy markets is such that the price and availability of crude oil will continue to determine, in large part, the speed of development and degree of penetration of, among others, renewable energy sources, of which wood energy constitutes an important part.

My comments to you today will be presented in four parts. First, I will take the perogative of the podium to briefly discuss the Canadian Energy Research Institute; who we are, what we do, and our place in the energy sector in Canada. Second, I will provide some brief comments on the place of renewable energy in the world energy market and, more specifically, the role of renewable energy in the Canadian energy sector. Third, I will summarize the major results and

key messages arising from our recently released study of the world oil market, entitled Stability Within Uncertainty: Evolution of the World Oil Market. Finally, I will offer a few conclusions and comments which I hope will help set the external environment for your deliberations over the next two days.

Introduction: Canadian Energy Research Institute

(See Appendix - Corporate Structure)

(See Appendix - Research Program Development)

Renewable Energy In The World Energy Market

The revolutionary developments in global trade and commodity transportation witnessed during this century gradually transferred the emphasis of determination of energy supply sourcing away from indigenous resources and towards the degree of industrialization and economic development of a given country or region.

(See Appendix - Primary Energy By Source, Canada 1870-1986)

For many of the industrialized countries, the pattern of energy use has paralleled that of Canada. In Fig. 3 I have shown the four key phases of energy use in Canada; first, an extended period of dependence on renewable energy, largely wood, followed by the displacement of renewable energy sources by coal in the early 1900s, and that by the rise to pre-eminence of crude oil as our source of primary energy. The fourth phase, in which Canada and most of the industrialized

countries currently reside, has been termed by the Japanese the Multiple Energy Era. Indeed, it is the opinion of many energy market analysts, and one shared by CERI, that the next twenty to thirty years will be characterized by the absence of a dominant energy source. Rather, we will witness increased competition at the burner-tip among various energy sources, and the pursuit of numerous energy options, aimed at avoiding reliance on imported energy fuels and maximizing our ability to respond to relative price changes among energy sources.

In other countries around the world, the move toward alternative sourcing of energy has proceeded at a widely differentiated pace, largely dependent on the economic resources of the country, the indigenous energy mix, and the political imperatives of environmental concern and exposure to a volatile and unpredictable world oil market.

In Brazil, virtually all of the automobiles currently produced are designed to run on a "neat" ethanol fuel, containing 80% ethanol.

In China, the environmental consequences of fuelling the coming industrial revolution on coal has yielded a rapid deployment of all available renewable energy alternatives, including what is the world's largest utilization of solar energy technology.

In India, the pursuit of bioenergy is expected to take a considerable share of the refined petroleum products market by the turn of the century.

In Western Europe and North America, the rapid ascendence of environmental issues to the top of the energy agenda will see tremendous changes in how these economies use energy, changes which will have significant implications for the renewable energy sector.

While availability and development of alternative energy supplies will be critical to the Multiple Energy Era, much of the adjustment will be seen on the demand side of the equation and, in particular, the ability of energy users to switch away from refined petroleum products and toward alternative sources of energy. In Canada, the degree of fuel substitution over the last decade has been remarkable. Crude oil's share of primary energy demand has declined from 55% in 1975 to 35% in 1986. Of note here is the significant growth in renewable energy consumption, along with electricity and natural gas, over that period.

The time frame shown on this Figure is particularly important, and brings me to the main thesis of my remarks today. The development of alternative energy sources and the speed of adoption of those energy sources over the last 15 years has been closely tied to the ascendence of OPEC in the world oil market and the dramatic price increases in world oil over the 1970s and early 1980s. In many respects, the resurgence of, in particular, coal and renewable energy sources in the world energy mix is the direct offspring of OPEC's success in driving up the real price of crude oil.

High crude oil prices created the economic environment which allowed for the development and deployment of new technologies, and the redeployment of old technologies, which brought forth the plethora of energy alternatives which we have at our disposal today.

Similarly, an extended period of low oil prices will have the opposite effect, depressing project economics and removing the commercial and political imperative for pursuit of these higher-cost alternative energy sources.

This is the economic reality of the world energy market today. Crude oil, which continues to possess the desirable properties of easy transportation, relatively clean combustion, and (currently) low prices, remains the benchmark against which energy options and alternatives are assessed. And, having created this undesirable offspring of readily available energy alternatives, it is clearly in the interests of OPEC, and oil producers in general, to attempt to maintain a price level which will discourage the further development of these alternatives.

Having put forward the importance of the role of world oil prices to the development of alternative energies, what then can we say about the future of world oil prices.

Stability Within Uncertainty: Evolution of the World Oil Market

Last month, the Canadian Energy Research Institute released a report which culminated a two year research effort

aimed at analyzing the fundamentals of the world oil market and examining the likely evolution of that market under a number of plausible alternative scenarios. The study was initiated in the fall of 1986, following the third oil price crash in which OPEC had exhibited its ability to destabilize the world oil market by driving prices down. Many analysts and advisors were left uncertain as to the direction of future movements in crude oil prices, let alone the magnitude.

The CERI board of directors instructed CERI officers to develop an analytical framework based on the underlying fundamental characteristics of the oil market. The framework was to be sufficiently flexible and disaggregate, however, to allow for the analysis of, among others the following question: In the event of a collapse of the OPEC cartel and the development of a "competitive" world oil market, what would be the resulting floor price for crude oil, in what areas of the world would oil production be affected, and what would be the likely duration of this competitive floor price?

In other forums since the release of this study, I have discussed at some length the methodology employed in developing our analytical framework, the structure and operations of the CERI world oil market model, and the strengths and weaknesses of our approach. For this particular forum, however, I will focus in on the key study results and the messages which we have drawn from our analysis.

(See Appendix - Reference Case Scenario)

I will deal today with three of the seven scenarios contained in the study. First, I will speak to the reference case scenario, which represents, in the view of the study authors, a most likely path for crude oil prices given a rational and well-behaved market and the absence of unforeseeable supply and demand shocks. I will also discuss the results of our competitive market scenario and a high resource scenario.

The Reference Case Scenario is so-called because it embodies a very reasonable set of assumptions regarding production levels for OPEC over time, non-OPEC supply potential, economic growth rates around the world, and the responsiveness of oil demand to changes in price and economic growth. The key input to the scenario, the level of OPEC production, sees OPEC output increasing gradually over the forecast period, from 18.8 MMb/d in 1988 to 27.4 MMb/d in 2000, a level that is 40% higher than current levels but significantly below the cartel's estimated current productive capacity of 34 MMb/d.

(See Appendix - "GOPEC" Production Restraint World Oil Prices)

The reference case price projection represents a readily sustainable price path, conditional on the assumed level of OPEC production. The principal trend is for slowly rising real oil prices through to the mid-1990s, followed by slightly accelerated price increases over the remaining forecast horizon. Prices reach $22.50 per barrel by 1995 and exceed $26.00 per barrel by 2000.

In our view, this price projection provides a very realistic picture of future oil market developments. The level of crude oil production assumed for the cartel does not require that OPEC reduce output quotas from current levels, and should be attainable with a reasonable degree of cartel unity. Steady demand growth and an eventual decline in non-OPEC production will allow the cartel to gradually increase both its market share and annual revenue.

Our reference case, then, is critically dependent on a rational and patient OPEC, willing to establish and abide by reasonable production quotas. This, however, will not necessarily be the case.

(See Appendix - Competitive Market Scenario)

The Competitive Market Scenario is an attempt to arrive at a reasonable price floor for crude oil, and to investigate the evolution of a non-cartelized market. The scenario is based on a breakdown of the cartel in 1989, with a gradual return to previous productive capacity by 1993, phased in according to the amount of time required to achieve this level of production in the various countries. Production in 1993 for the cartel as a whole reaches 33 MMb/d; an additional 1 MMb/d of productive capacity is assumed to be brought on stream in each subsequent year, centered in the reserves-rich Persian Gulf region.

(See Appendix - Reference and Alternative Scenario Price Projections)

Dramatic as these developments are, our estimate of the competitive floor for oil prices is somewhat higher than other estimates. The result, of course, is critically dependent on the speed of development of the massive Middle East reserves. If the OPEC taps could be opened more quickly, then the floor price could well prove to be lower.

Indeed, one would expect to see downward price spikes, of short duration to reach well below the $9.00 per barrel mark, due to market over-reaction to the collapse of the cartel. It is instructive to note that the price crash of 1986, which saw $10.00 per barrel crude oil prices, still yielded a 1986 annual average W.T.I. price in excess of $14.00 per barrel.

(See Appendix - Competitive Market Scenario)

A useful benchmark for assessing the different OPEC strategies is the net present value of the revenue stream accruing to OPEC under the alternative scenarios. As shown in this Figure, the reference case scenario yields the greatest net present revenue stream to OPEC. Indeed, this market strategy represents a "best case world" for the cartel. Under no other scenario examined did OPEC receive a greater return to production over the forecast period.

This includes the competitive market scenario. More important, the revenue losses under this case are carried disproportionately by those OPEC members with the least existing surplus capacity--those also being the countries with the smallest reserves base and the most pressing financial needs.

Also shown here is the revenue yield under our GOPEC or mini-cartel scenario, which assumed that a four-member mini-cartel--consisting of Saudi Arabia, Kuwait, the U.A.E., and Qatar--would emerge to protect a price floor of $15.00 per barrel. The key result to draw from this scenario is that these Persian Gulf producers would be better off, in revenue terms, to open up the taps rather than to try and regulate the world oil market on their own. It appears clear that the other Opec members need OPEC more than the reserves-rich Persian Gulf countries do.

The final simulation which I would like to address today is termed the High Resource Scenario. This scenario is predicted on the surprising resilience on non-OPEC production in the fact of declining crude oil prices over the last five years, and the consistently upward revision of estimates of ultimate potential in the non-OPEC regions. In this scenario, we set estimates of ultimate potential at the optimistic (or 5% probability) level, which results in a greater return to a given amount of drilling activity and, hence, a higher production profile in the affected countries over the forecast horizon.

(See Appendix - Price Projections)

This Figure shows the price projections under the three scenarios discussed. The impact on future prices of the high resource scenario is significant. With OPEC production held at the same levels as in the reference case, the increase in non-OPEC production generates a lower price path: prices fall in

1988 to under $17.00 per barrel, recovering to just over $22.00 per barrel by the year 2000, 20% lower than in the reference case.

In our view, the high resource scenario provides a very legitimate low oil price path. We accord it virtually equal probability of occurence relative to the reference case scenario.

Conclusions And Key Messages

What, then, are the key messages which I would like you to take away from this presentation.

First, the world oil market will respond to market un-certainties over the short-term, but will follow a stable, upward growth path over the long term. This message is premised entirely on the strength of the fundamental supply and demand characteristics underlying the oil market.

Second, those involved in the energy market should focus more attention on the fundamentals of the oil market, and less on the short-term fluctuations and volatility characteristic of that market.

Third, virtually all of the short-term price risk associated with the oil market resides on the downside. The study authors were unable to generate a single, plausible market scenario that resulted in a price path above that of our reference case scenario.

From these messages can be culled a number of implications for the Canadian energy sector.

(See Appendix - Implications for the Various Energy Sectors)

First, for energy consumers, our research would suggest that price instability will be greater over the period to 1995 than later in the forecast horizon. Declining non-OPEC oil production, rising demand and gradually increasing OPEC production and market share should all serve to strengthen OPEC unity, and oil market stability, through the 1990s. Security of supply, once a central and emotional issue in Canada, is likely to remain a minor issue over the next decade, given our projections of world crude oil requirements relative to available supply.

For crude oil producers, and for this particular audience, I would draw your attention to the second conclusion; that the downside risk exposed in this study be explicitly incorporated into strategic planning and project assessment. The sequence of events required to achieve a $25.00 per barrel oil price in 1990 (or even 1995) is largely inconsistent with market fundamentals. Similarly, while it is possible for crude oil prices to be driven below $10.00 per barrel, it is unlikely that such low prices would be sustained for any length of time.

Finally, for energy policy-makers: while adherence to long-term market fundamentals and appropriate down-playing of short-term market imbalances are essential features of sound energy policy, care must be taken to give sufficient weight to the risk contained in long-term price projections. The decision to prebuild production capacity on the expectation of higher oil prices in the future must be couched in the explicit

understanding that project economics may not be realized when the time comes to initiate production.

Second, major energy-saving gains remain to be made on the demand side of the energy equation in Canada, and alternative energy sources are positioned to take a greater share of the energy market currently served by crude oil products. It is important to Canada's energy future that policy-makers recognize and support these potential energy initiatives, and not be overly swayed by the economic development benefits of large-scale energy projects.

That concludes my comments to you today. I am sure that many in this audience were hoping to hear a more optimistic story regarding oil prices, given the positive impact of the same on renewable energy project economics. For others, where coal-fired thermal electricity represents the challenge, I would urge you to see our recent study on industrial cogeneration in Canada. In any event, I hope that my comments have provided a useful backdrop for your deliberations over the next two days.

APPENDIX

GRAPHS, SUMMARY

FIG. 1

CANADIAN ENERGY RESEARCH INSTITUTE

CORPORATE STRUCTURE

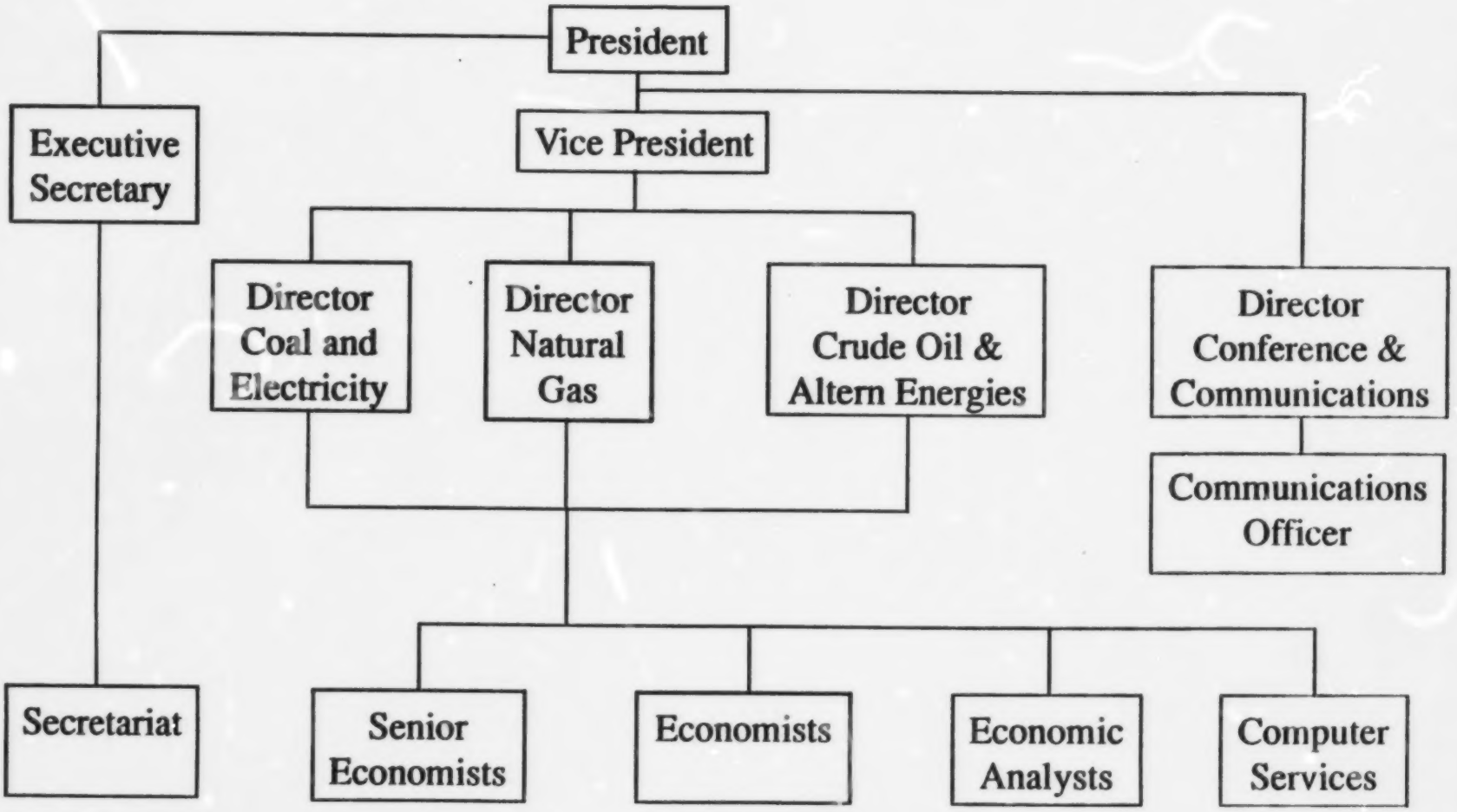


FIG. 2

RESEARCH PROGRAM DEVELOPMENT

FIG. 3

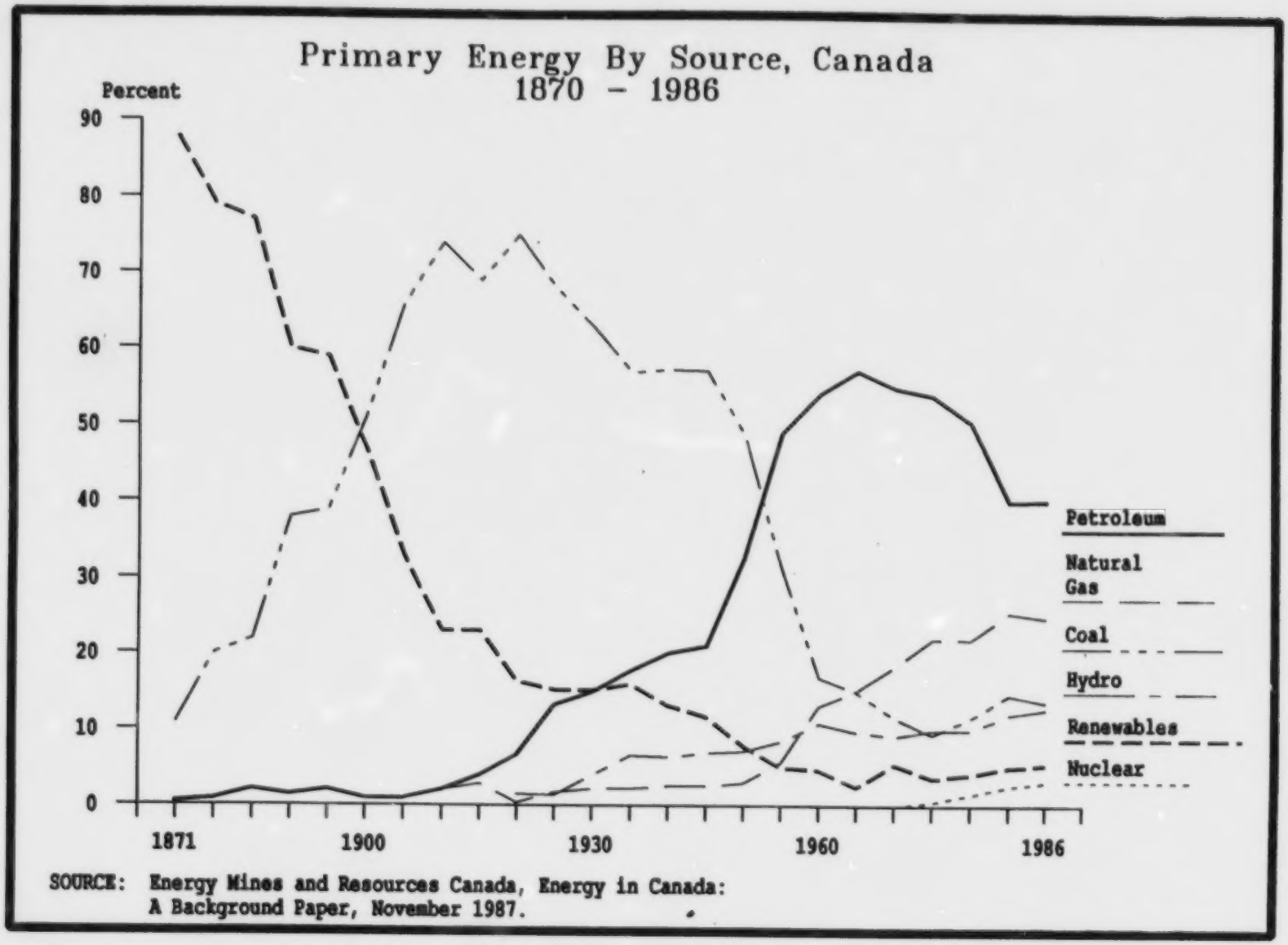

Primary Energy By Source, Canada
1870 - 1986
Percent
90
80
70
60
50
40
30
20
10
0
1871
1900
1930
1960
1986
Petroleum
Natural Gas
Coal
Hydro
Renewables
Nuclear
SOURCE: Energy Mines and Resources Canada, Energy in Canada: A Background Paper, November 1987.

FIG. 4

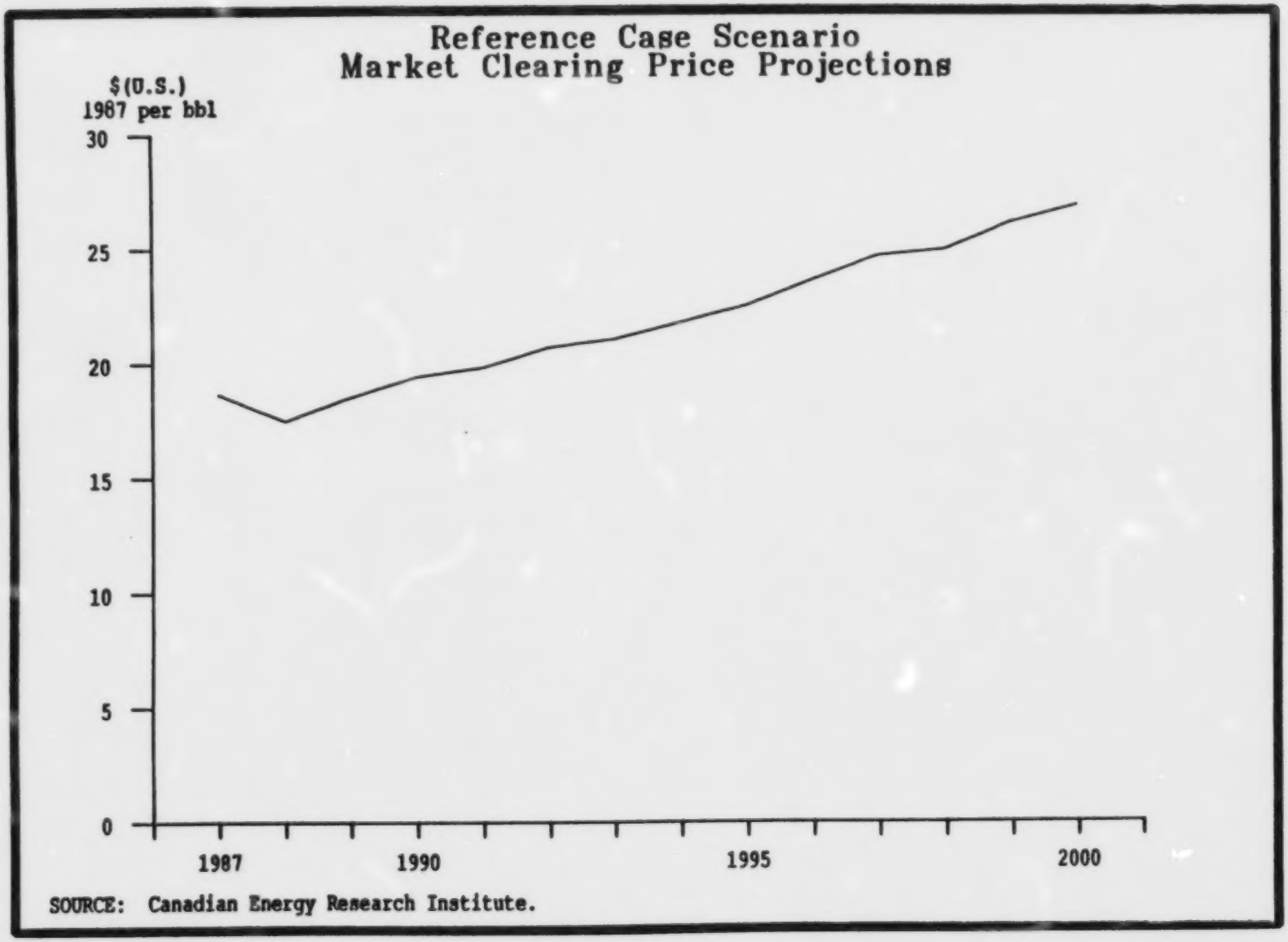

Reference Case Scenario
Market Clearing Price Projections
$(U.S.)
1987 per bbl
30
25
20
15
10
5
0
1987
1990
1995
2000
SOURCE: Canadian Energy Research Institute.

FIG. 5

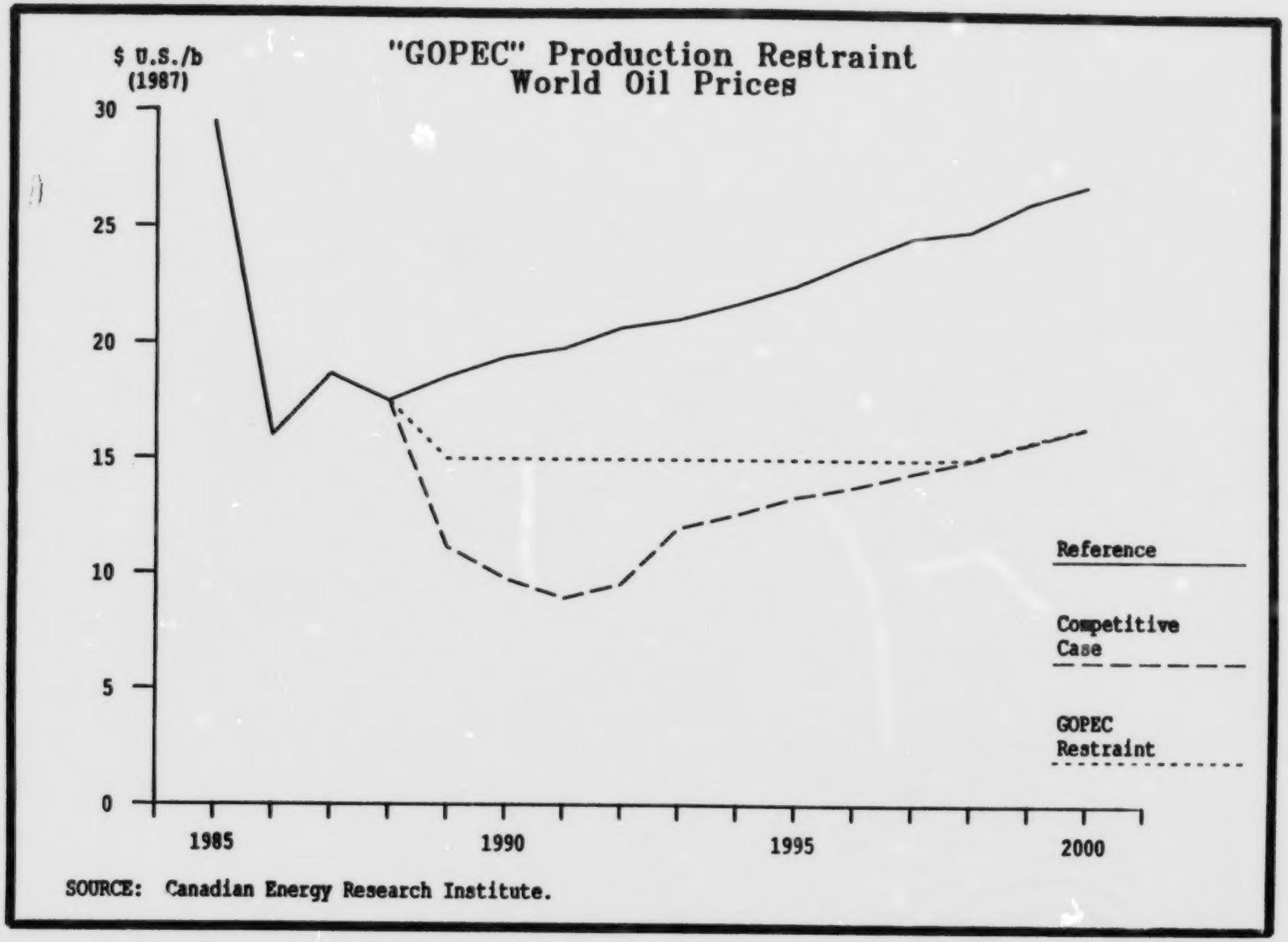
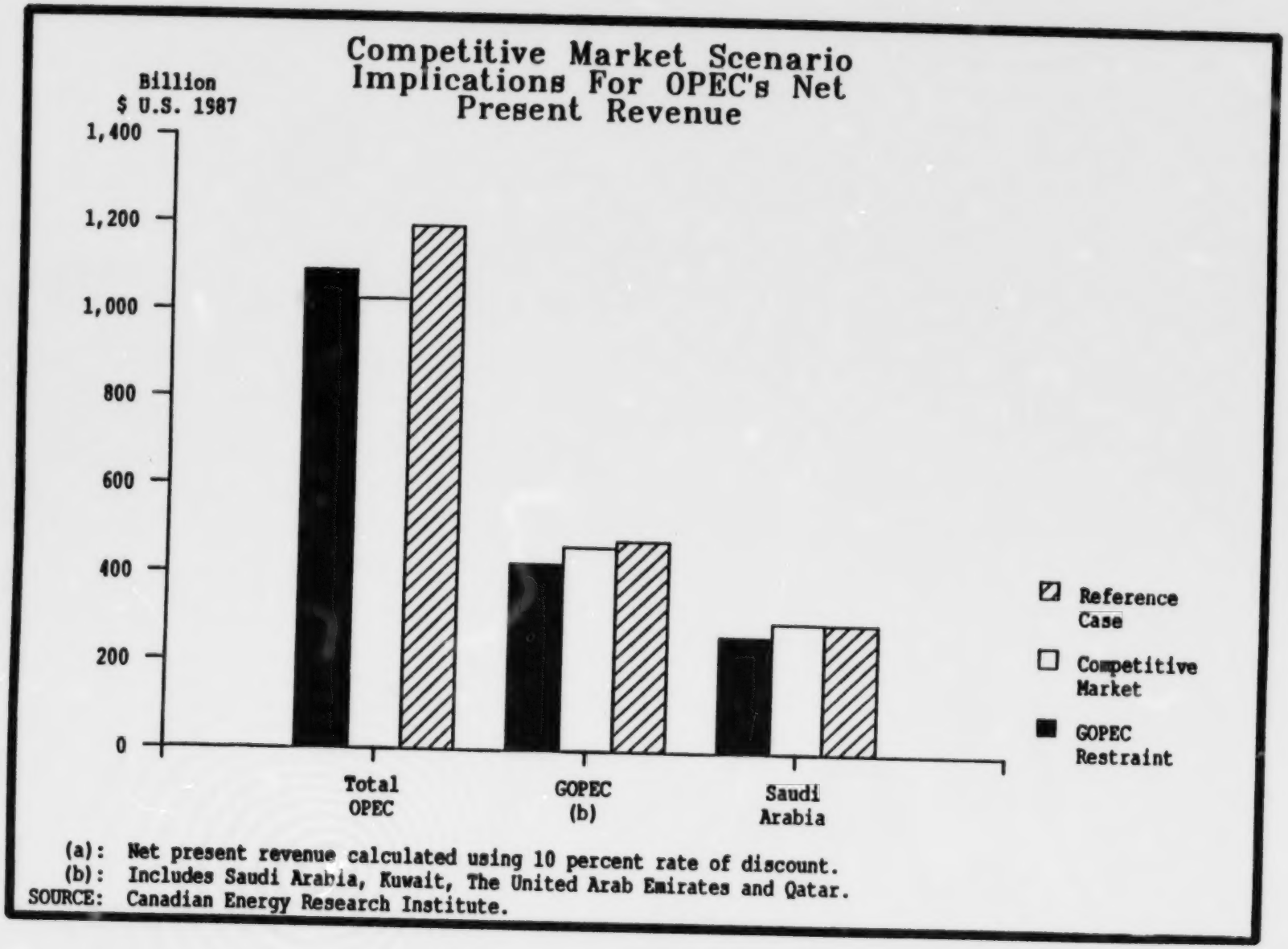
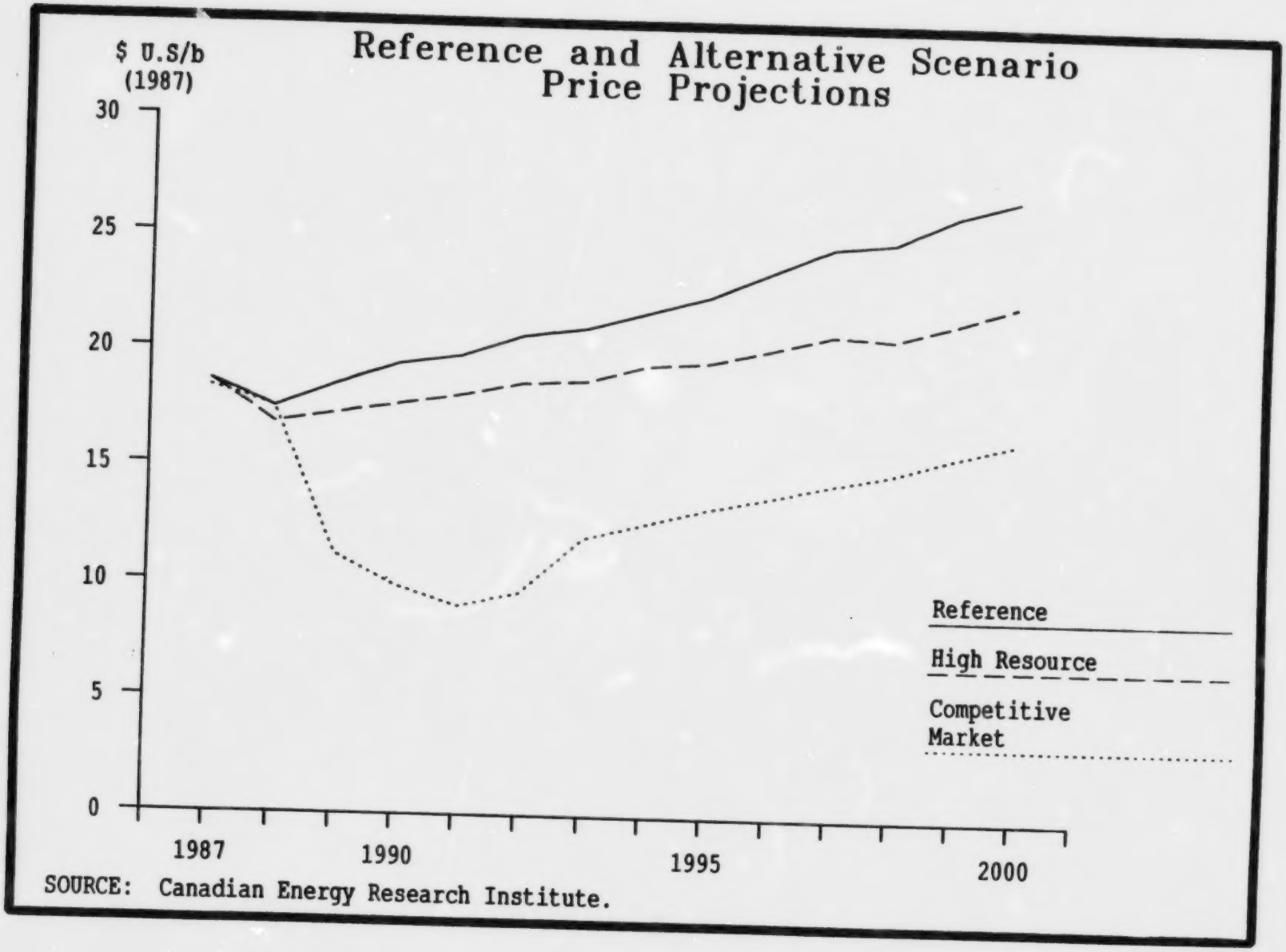

"GOPEC" Production Restraint
World Oil Prices
$ U.S./b
(1987)
30
25
20
15
10
5
0
1985
1990
1995
2000
Reference
Competitive Case
GOPEC Restraint
SOURCE: Canadian Energy Research Institute.

FIG. 6



(a): Net present revenue calculated using 10 percent rate of discount.
(b): Includes Saudi Arabia, Kuwait, The United Arab Emirates and Qatar.
SOURCE: Canadian Energy Research Institute.

FIG. 7



SOURCE: Canadian Energy Research Institute.

FIG. 8

5. Implications for the Various Energy Sectors

For Consumers

- **Instability in crude oil prices, and hence in relative energy prices, is likely to be greater over the period to 1995 than later in the forecast horizon.**

- **Security of crude oil supply is likely to be a minor concern over the next decade.**

For Producers

- **Focus strategic and corporate planning initiatives firmly on market fundamentals.**

- **Planners should recognize the downside price risk exposed in our sensitivity analyses and incorporate this into their strategic planning exercises.**

- **Do not count on much higher oil prices. The sequence of events which would be required to achieve a $25 (U.S.) per barrel oil price in 1990 (or even 1995) is largely inconsistent with market fundamentals.**

FIG. 9

5. Implications for the Various Energy Sectors (cont.)

- While adherence to long-term market fundamentals and appropriate downplaying of short-term market imbalances are laudable approaches to long-term policy planning, care must be taken to give sufficient weight to the risk associated with long-term price projections.

- Major energy-saving gains remain to be made on the demand side of the oil equation, and alternative energies are positioned to take a greater share of the oil market in Canada. It is important that the public sector in Canada pay appropriate attention to these demands and supply measures, and not be overly swayed by the economic development benefits of large project developments.

- Finally, the current study provides implicit support for the current government stance on oil market decontrol and deregulation in Canada. The future health of Canada's oil industry will once again test the strength of Canada's public sector support for market deregulation; Canadian energy producers and consumers should both hope that this support will remain strong.

WOOD ENERGY IN PERSPECTIVE

D.L.P. Strange

Energy, Mines and Resources Canada

Introduction

First, I would like to express my thanks for being invited to talk to you about the wood energy picture and how I see it unfolding in the future. I'm particularly pleased because I can spend a little time blowing trumpets for those of us who have been involved with wood energy during the last decade; I think we have a lot to be proud of.

I can also look down the road and present some views on the future. I do not believe that the future of bioenergy is simply an extension of what has happened in the past; there are a whole new set of issues, public perceptions and ground rules. In discussing these I can be a little more philosophical than I otherwise might be.

I am also going to spend a few minutes linking the present with the future, that is, showing how I think we can get from here to there. This gives me the opportunity to talk about a series of initiatives which we have developed within the Department of Energy, Mines and Resources which, we believe, will help us face up to the challenges of a changing world.

Historical Perspective

Renewable energy currently plays a significant role in Canada's energy situation, accounting for almost 7% of total primary energy requirements. Almost all of this current

contribution is from wood, as wood waste, and spent pulping liquor in the pulp and paper industry, and from wood used for space heating in the residential sector.

This 7% figure (equivalent to just over 544 PJ or 83 MBOE/yr) is even more significant when it is realized that in 1975 the contribution of wood energy to Canadian primary energy requirements was only 4% (Fig. 1).

Although it is not possible to identify with any certainty the reason for this increased use of wood, there are undoubtedly a number of factors, not the least of which have been concerns related to security of energy supply. For most of Canada's history our energy wealth has allowed us to take energy security for granted. Since the 1970's, however, security of supply- principally regarding oil and natural gas - has become an important element of Canadian energy policy.

The events of the 70's and early 80's related to increased power of the Organization of Petroleum Exporting Countries (OPEC), such as production cutbacks and selected embargoes, resulted in world oil prices quadrupling. Even although we are an energy rich country, we were not immune to these events. We became very protectionist of our resources, especially when told that our oil and gas resource base was being exhausted at a faster rate than we previously thought.

The federal government reacted with a number of initiatives designed to decrease our dependence on imported oil

and increase our energy security. Close to our hearts were those initiatives which followed from the establishment of the renewable energy R&D program at NRC in 1976 and the establishment of our own Renewable Energy Resources Branch in 1977. (Fig. 2)

In the bioenergy area there were a number of specific federal initiatives, in many cases parallelled by provincial activities, designed to promote or accelerate the use of bioenergy in Canada. Research and Development Programs (now represented by the Bioenergy Development Program - BDP) were implemented on an ongoing basis to ensure the development of new methods and technologies to substitute biomass for non-renewable fuels and chemicals. Activities under such programs have been carried out through contracts with industry, Universities and research organization and have been designed to address the barriers of high risk and cost of developing and introducing new technologies.

Other programs (such as ENERDEMO, FIRE and COSP) were designed to demonstrate or to assist market penetration of commercially ready technologies. Other benefits of these programs were to 1) increase the awareness of available technologies, 2) increase expertise, 3) encourage efficiency and the use of safety through the development of standards, eg. woodburning appliances in the residential sector.

Two programs of particular interest (the Remote Communities Demonstration Program, RCDP; and the Alternate Energy Development Program, AEDP) were designed to address the needs of particular market niches, such as the remote north and Prince Edward Island, where the availability of more conventional energy sources is restricted or costs are high. I think that the P.E.I. experience, with federal/provincial shared responsibilities and funding, has proven very successful. Not only are they now operational in P.E.I., over 80 woodchip burning installations which have been supported through this program and which use over 40,000 tonnes of green chips annually, but the use of wood for energy is helping provincial endeavours to improve old or diseased forest stands.

These activities, reflecting the broader concerns of Canadians related to energy security and in parallel with activities supported by provincial governments and private sector, have been instrumental in achieving significant results in the bioenergy area.

However, the price of more conventional fuels, such as oil, has now dropped considerably and stabilized around $15 U.S. barrel. Programs, such as FIRE, are winding down with no likelihood of revitalization, reflecting federal government policy of letting the market place make decisions rather than forcing it with incentive programs. The money is just no longer available for such programs. It is against this

background that we need to examine the future for bioenergy in Canada.

Wood Supply

To a large extent, other than ensuring the existence of acceptable estimates of the availability of wood or other biomass for energy, we in the Renewable Energy Branch have not directed attention towards bringing about changes in the supply side of the equation. However, considerable work has been undertaken by CFS under the ENFOR (Supply) Program and by a number of other groups interested in, for example, energy plantations.

For biomass to be attractive as a fuel it must, in addition to being of widespread availability, be obtainable at low prices in order to be competitive with other, more conventional, fuels.

Within the forest itself, and including mill and pulping liquor residues, we estimate that on an annual basis there are available some 112 million tonnes of biomass (Fig. 3), 50 million tonnes of which are available at under $12 per BOE or less. This is equal to about $30 per delivered tonne. Such moderately low cost biomass material is available from forest related activities and occurring as salvage, merchantable surplus standards, logging residues, etc., as well as from pulp and paper industries, furniture manufactures and,

in the case of nonwood biomass, occurring as municipal and industrial waste, animal and food processing wastes.

Currently, we estimate that just over 25 million tones of forest biomass (not including spent pulping liquors) are in use in Canada. From the supply side it appears, therefore, that we have not reached the limits of available biomass. However, there is much regional variation as to the nature and supply of this biomass material which will significantly impact on the technologies used for its use for energy.

Energy Supply - Bioenergy Infrastructure

In very general terms, the two most significant achievements in bioenergy use over the last few years have been the development of an industrial capability and support infrastructure to provide bioenergy components, systems and technical expertise to a worldwide market and, secondly, the generation of significant public awareness as to the capabilities and limitations of bioenergy sources.

The majority of energy derived from the combustion of biomass materials is used in the pulp and paper industry, where the combustion of wood and pulping wastes accounts for about 50 percent of this industry's energy use and 17 percent of total industrial sector energy demand.

In the residential sector, it is estimated that over 2 million Canadian households rely on wood as either a primary or a secondary space heating source, accounting for 13 percent of residential sector energy demand.

This energy contribution has been accompanied by advances in biomass combustion technology, and the development of a significant bioenergy equipment manufacturing capability in Canada. The number of companies fabricating bioenergy combustion equipment has grown from no more than ten in 1975 to nearly 50 in 1983. Technology has progressed from field erected systems and inefficient wood stove designs to standard design units for institutional space heating systems which can utilize a range of biomass including wood, agricultural and municipal wastes, and efficient residential wood heating systems. The parallel with this has been the development of standards and operating procedures which can help ensure safe and efficient operation of these sytems. New technologies from other countries have been introduced into Canada, and Canadian companies have improved upon these technologies and incorporated such improvements into their own product designs.

These industry development achievements have been complemented with progress in novel technologies to utilize bioenergy which have not yet reached full commercial status. Examples include the conversion of biomass to ethanol and other coproducts, the development of wood gasification, anaerobic digestion and waste combustion technologies, and advancement in the transportation and handling of biomass fuels, and resource management and assessment techniques for the biomass source.

This progress has paved the way for continued achievements in bioenergy technology and increasing bioenergy contribution.

It is estimated that these activities translate into total annual bioenergy revenues of between $500M and $550M annually, involving nearly 2000 firms.

Present Context

From almost a standing start, therefore, the activities of the last ten years in bioenergy have resulted in a number of bioenergy technologies becoming fully commercial in the domestic marketplace, while others are still in various stages of development or demonstration.

Although considerable impetus has been given to activities in the bioenergy area through concerns related to energy security, one of the most prevalent forces driving market attractiveness of the various bioenergy technologies has been their economic competitiveness compared to other alternatives. With declines in oil prices from approximately $40 U.S. barrel in 1984 to under $15 today, this situation has changed dramatically. Bioenergy can, however, still be economically competitive. It is important to determine these market sectors and technologies where bioenergy use continues to appear attractive and sustainable without additional outside financial support.

Examination of current economic attractiveness (from a social or national perspective with all costs calculated over

the 20-year assumed life cycle for systems at 7% real discount rate, assuming a rise in the price of oil from $12 U.S. barrel to $25.70 U.S. in 2005) shows that in the commercial and institutional sectors, biomass heating systems can be economically attractive relative to oil and electricity but that they are not competitive with natural gas (Fig. 4).

In the industrial sector, wood and other industrial waste fired process heating systems can be economically attractive relative to heavy fuel oil and natural gas depending on the cost of obtaining the waste material. Processed wood fuels and waste material with a significant transportation cost component are not economically attractive.

In the remote sector, biomass energy can be economically attractive relative to diesel generated electricity on a site specific basis and biomass cogeneration systems can be economically competitive with grid electricity supply.

Of particular interest is the fact that while declining oil prices have reduced the economic attractiveness of bioenergy systems they have not, in general, removed attractiveness where it existed before. Additionally, the opportunities in niche markets or those areas were conventional energy costs are high (e.g. northern remote communities and Atlantic provinces) appear particularly favourable for bioenergy use.

While analyses of this type serve primarily to reinforce our inherent understanding of economic attractiveness, of greater interest is to use such analyses to identify those areas in which there continues to exist economic potential.

An estimate of the potential energy contribution from applications of bioenergy technologies that are cost effective in 1988 is 544 petajoules (83 MBOE/yr). The total economic potential remaining for bioenergy technologies that are cost effective now at forecasted conventional energy prices is estimated at 111 petajoules (17 MBOE/yr); Fig. 5.

However, these calculations are based on the state of development of technologies today. The current economic and market competitiveness of bioenergy systems is expected to improve over time through the combined effects of conventional energy price increases and improvement in cost/performance relationship for bioenergy technologies. These are predicted to lead to additional economic potential for renewable energy contributions in the future.

Recent R&D achievements in wood harvesting procedures, wood fuel quality control and supply automation, materials handling, fuel processing and combustion efficiency point to the ability to reduce the cost of biomass fuels and to allow the introduction of a new generation of more convenient and efficient combustion systems.

Advances occurring now in biochemical technology are expected to provide opportunities to refine biomass materials into a wide variety of fuels and chemicals that will be able

to substitute for petroleum products. One example of this opportunity is the production of fuel ethanol from the cellulose component of biomass material with use being made of the associated hemicellulose for furfural production and the lignin used as a phenol replacement.

Taking considerations such as these into account, and using the best judgement of technology experts as to what magnitude of technology cost improvements are possible, the additional bioenergy contribution potential that could become economic by the year 2005 (as a result of conventional energy price increases and biotechnology improvements) is 85 petajoules (13 MBOE/yr).

In total, therefore, by the year 2005 there is the potential to increase the use of bioenergy by 196 petajoules. This almost doubles the current contribution from roundwood use in the residential sector and from forest biomass if we exclude the 252 petajoules currently coming from the use of spent pulping liquor. I have excluded energy from pulping liquor here since this represents a very specific market niche which is completely saturated.

Obviously, the price of conventional energy sources will profoundly affect the continued penetration of bioenergy use into those markets where potential exists. We know from past experience the difficulties in predicting price levels even in the short-term. Therefore, any estimate of economic

potential must be made with careful consideration of the sensitivity of the estimates to changes in this important factor.

We do believe, however, that there continues to be considerable potential for achieving system cost/performance improvements through further research and development and through economies of scale in production.

The Future

Having identified some of the opportunities which exist for bioenergy does not necessarily help us to ensure that the full potential of these opportunities is realized.

From the least optimistic point-of-view, there is no longer the push of high, or wildly fluctuating, oil prices to encourage adoption of bioenergy technologies. The prospect of near-term world surpluses of both oil and gas have caused complacency and directed attention away from energy efficiency and diversity activities which, interestingly enough, are still economic and are being undertaken by our major trading partners.

Additionally, there is currently in existence a restrained fiscal climate produced, in part, by a desire to decrease the federal debt. The large ticket programs, such as FIRE, are in wind down. It could also be argued that the more readily accessible market sectors (such as the forest products industry) have already been penetrated and saturated.

From a far more optimistic point-of-view, our experiences over the last 10 years have enabled us to understand, and to identify with some degree of certainty, ways in which bioenergy technologies can be encouraged without complete dependence on high levels of federal funding.

Firstly, the sorts of analyses discussed previously allow us a considerable level of comfort in knowing which technologies or systems are, or will be, economically attractive. We can then focus on the range of non-price barriers which recent analyses in Canada and other IEA countries have shown will continue to hamper much of the potential from being achieved.

These barriers include lack of information or (failure to target available information) on viable technologies and their applications, lack of confidence in performance of new technologies, restrictive investment criteria applied by energy users as compared to energy suppliers, and perceived financial risk.

Secondly, the widespread occurrence of bioenergy resources and the labour intensive nature of their use made bioenergy attractive from a regional development perspective.

Thirdly, there is an increasing realization amongst Canadians that the energy industry is not restricted to oil, gas and hydro but that it includes conservation and alternatives such as bioenergy, the latter being seen as job generating.

Finally, and possibly of greatest importance, is the environmental issue and the increasing attention it has assumed, both in the eyes of the public and in the minds of decision makers in the energy field. Over the last decade, in the public agenda, attention to energy production has declined, whereas emphasis on environmental concerns has doubled.

Environmental concerns are now focussed on health risks (toxic wastes) and the potential economic damage that might result from poor planning with respect to such environmental issues as acid rain or carbon dioxide buildup. Economic and health issues predominate, rather than the aesthetic values of fifteen years ago.

A key feature of the government's increasing environmental awareness is reflected in the recognition that environmental considerations must be fully integrated into the planning process for economic and energy development activities. The Brundtland Commission, and more recently the National Task Force on Environment and Economy, have convincingly stated the case for this fundamental change in our planning and decision making processes. This position is reinforced in the report "Energy and Canadians into the 21st Century - A Report on the Energy Options Process" where a comprehensive framework of energy policy principles is proposed to address the challenges facing Canada's energy economy into the 21st century. A total of seven principles are enunciated, one of which deals with energy and the environment:

"environmental goals should be accorded the same importance as other economic and social goals in the planning, development and use of energy."

More specifically, at the recent international conference "The Changing Atmosphere" in Toronto in June, 1988, it was agreed that a strategy would be developed to decrease CO_2 emissions in Canada by 20% by the year 2005.

Renewable energy resources, including bioenergy, can have a very great role to play in helping to ensure a more environmentally appropriate energy mix for Canada.

Although it is uncertain as to the contribution of CO_2 from combustion of all fuels (fossil and renewable) in Canada to global increases in CO_2, it is apparent that increased efficiency of combustion will decrease the amount of CO_2 produced, irrespective of the nature of the fuel.

This leads us to believe that continued efforts to improve efficiency of use of all fuels is important. However, the use of wood rather than conventional fossil fuels has several advantages from an environmental perspective. Firstly, if wood used for energy is accompanied by reforestation there can be substantial decreases in net CO_2 release. This is especially true if old, diseased or dying, stands of trees are used for energy and are replaced with young, healthy trees as is currently being done in many parts of Atlantic Canada.

Secondly, burning wood does not contribute to SO_2 or NO_x release, products which are associated with the combustion of more conventional fuels such as oil, coal and natural gas, and which are associated with a number of environmentally undesirable effects, such as smog and acid rain.

Finally, the residue arising from woodburning is almost completely inert and can be safely disposed of without the need for special containment.

A further environmentally linked issue is the proposed phase-out of lead in gasoline by the year 2000. Alcohol has considerable merits for use as a lead replacement and as an octane enhancer, not the least of which is its low environmental impact. Although, currently, the economics are not attractive, there is the potential of replacing lead with alcohol generated from wood.

However, it would be extremely shortsighted to imply that the use of wood for energy does not present potential environmental problems. Depending upon the type of combustion process used, industrial scale combustion can produce high levels of particulates or other products of imcomplete combustion. The new generation of residential woodburning appliances, with their capability for controlled air access which can allow pyrolysis of the fuel can, as a result of improper operation, release large quantities of unburnt products with concomitant concerns for health and safety.

It is interesting to predict whether these environmental concerns will help or hinder the continued movement of bioenergy technologies into the marketplace.

Currently, there is a perception that a new generation of emissions regulations will be promulgated which will be almost impossible to meet without tremendous expenditures on post combustion cleanup devices. While these might be appropriate for large scale installations, the costs involved would be prohibitive for the smaller scale applications such as institutions and small businesses. At this time I will reserve judgement as to what will be the ultimate outcome, but I am convinced that most woodburning facilities, correctly operated, can be environmentally acceptable. Before we are able to reach this understanding I am aware that there is a need for an increase in activities related to emissions and performance monitoring.

It is interesting to note that increased environmental concerns can be advantageous to encouraging bioenergy use in Canada in another way.

One of our major ongoing thrusts is research and development in order to ready those technologies for the next round of market opportunities which will continue to ensure future security of energy supply. A number of these technologies (such as liquefaction; some types of gasification; ethanol from cellulose) do not appear economically attractive

in the near future. However, their economic attractiveness could improve markedly if competing technologies (including wood combustion) are subjected to increased emissions control and associated costs.

From Here to There

In order for these thoughts to have very much bearing on what actually will happen, they need to bear some relationship to other federal government thinking. Or, more appropriately, I'd like to think that these thoughts have been instrumental in influencing other government thinking! Irrespective of who has influenced whom, the Minister of Energy, Mines and Resources, The Honourable Marcel Masse, in August this year announced a new Energy Efficiency and Diversity Initiative, known as EED.

The primary objectives of EED are to enhance Canada's industrial competitiveness, energy security, physical environment and quality of life through the promotion of efficiency in energy consumption and diversity of energy sources and technology.

This new initiative is based on the experience gained from energy activities of the last few years, but considerably broadened to ensure that energy is placed into a more realistic perspective against the host of associated issues. This new initiative is intended to: enhance our international trade competitiveness; to protect and improve environmental quality;

to minimize disruptions from possible future oil supply or price shocks; to increase export opportunities and trade; and to stimulate labour intensive activities in a regionally sensitive manner. The overall desire is that it will allow the market to work without our major intervention.

We have received a five-year mandate for this initiative, but our financial resources have been reduced significantly. Therefore, we need to be innovative as to how we can best use other people's money to help finance activities under this initiative. For example, we are discussing very closely with our provincial counterparts to ensure cooperation and avoid duplication. Export thrusts we intend to pursue with the Department of External Affairs and agencies such as CIDA. Closer to home, we intend to pursue our eastern Canadian initiatives through mechanisms such as EDRA's, hopefully using funds from regional development agencies such as ACOA.

More specifically, we will continue our thrusts in R&D at a level of support similar to that of the last few years. We will, however, be directing more attention towards those technologies which have short to medium term potential. I can see an increased thrust towards identification and possible amelioration of adverse environmental effects of bioenergy technologies, ideally in cooperation with our associates in various environmental agencies.

We will also be seeking increased levels of outside funding for R&D projects especially as a particular technology approaches commercialization.

In the demonstration area we will be increasingly selective and will only support those demonstrations which are truly unique commercially and economically and levels of federal funding will be at most 25% of the total. We simply do not have funds for multiple demonstrations.

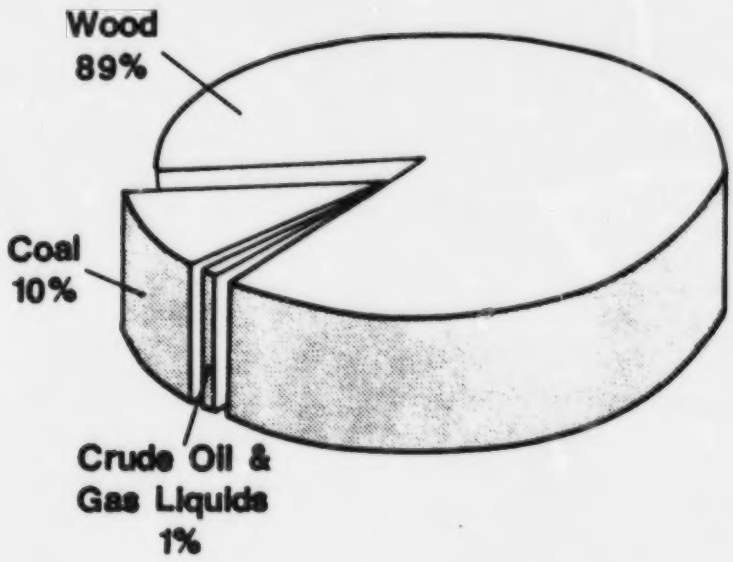
For those technologies which are already demonstrated or have entered the marketplace we will be more active in our information activities, relying heavily on our experiences in the last few years. Where there are environmental benefits arising from the use of bioenergy technologies we will feature these in our information activities.

What is apparent is that in all our activities, in order to maximize our available resources, we must continue to foster stronger relationships with our provincial and private sector associates in the bioenergy area.

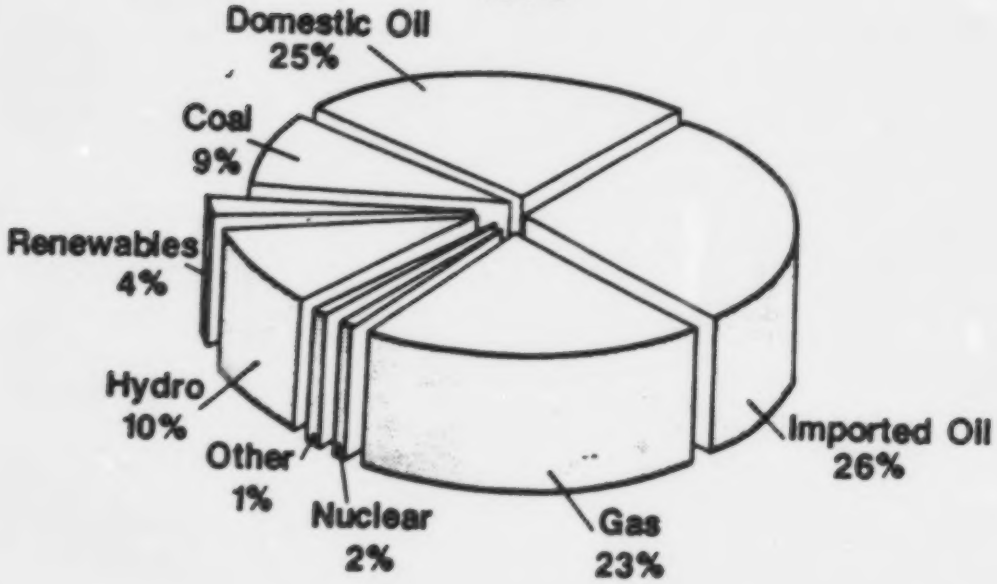
Conclusion

In conclusion, I have tried to put bioenergy in perspective and to paint a realistic picture for its development in today's economic, social and physical environment. I believe there is potential for continued wood use in Canada but to realize this potential we must become increasingly willing to work together to identify those technologies which are most likely to be winners and to pool our resources to back them.

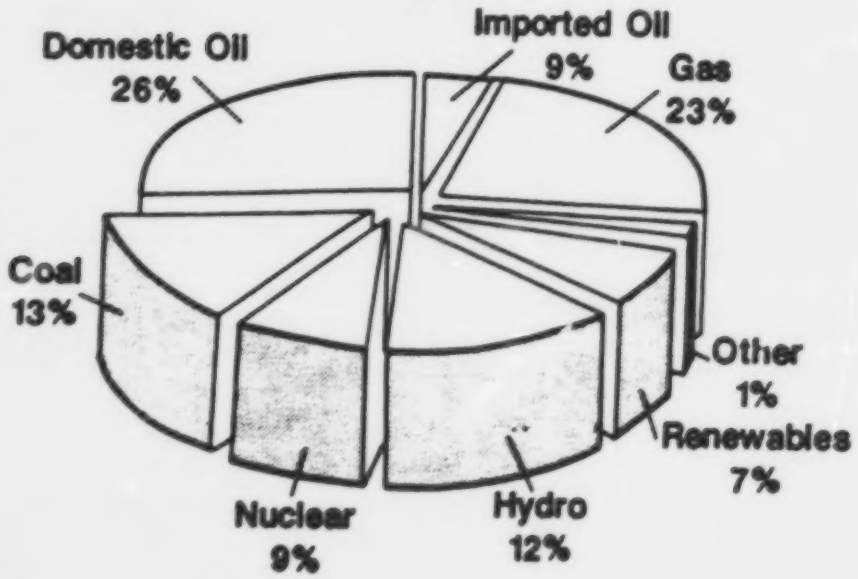
Canadian Energy Sources
1867



Canadian Energy Sources
1975



Canadian Energy Sources
1988



HISTORY OF CANADIAN RENEWABLE ENERGY INITIATIVES

1973 OPEC OIL EMBARGO

1976 INITIATION OF R & D PROGRAM

1977 RENEWABLE ENERGY RESOURCES BRANCH ESTABLISHED

1978 ANNOUNCEMENT OF 5-YEAR $ 380 MILLION PACKAGE INCLUDING RENEWABLE ENERGY PROGRAMS:
- FOREST INDUSTRY RENEWABLE ENERGY (FIRE)
- ENERGY TECHNOLOGY DEMONSTRATION PROGRAM (CREDA's)

1979 FURTHER OPEC OIL-PRICE HIKES

Fig. 2

HISTORY OF CANADIAN RENEWABLE ENERGY INITIATIVES (cont'd)

1980 NATIONAL ENERGY PROGRAM
- –EXPANDED RENEWABLE ENERGY PROGRAMS
- –CANADA OIL SUBSTITUTION PROGRAMS (COSP)
- –REMOTE COMMUNITY DEMONSTRATION PROGRAM (RCDP)

1983 ENERDEMO CANADA PROGRAM ($80 MILLION)

1984 SHUT–DOWN OF R & D PROGRAM AT NRC

1985 NATIONAL CONSERVATION AND ALTERNATIVE ENERGY INITIATIVE (NCAEI)

1985 ALTERNATE ENERGY DEVELOPMENT AGREEMENT P.E.I – ERDA

1986 INTERNATIONAL OIL PRICE COLLAPSE

Fig. 2 (Cont'd)

BIOMASS SUPPLY

FOREST BIOMASS: .SAWDUST .BARK .PULPING LIQUORS .LOGGING RESIDUES .UNMERCHANTABLE SPECIES	**112 MILLION TONNES PER YEAR** .APPROX. 300 MILLION BOE OR 25% OF PRIMARY ENERGY DEMAND 50 MILLION TONNES AVAILABLE AT $12 PER BOE OR LESS WELL DISPERSED ACROSS CANADA
AGRICULTURAL BIOMASS: .STRAW .ANIMAL WASTES .FOOD PROCESSING WASTES	**EASTERN CANADA**
MUNICIPAL AND INDUSTRIAL SOLID WASTES:	**DENSELY POPULATED URBAN AREA**
PEAT:	**SECOND LARGEST PEAT RESERVES**

Fig. 3

1988 Institutional/Industrial Sector Supply Prices

Conventional and Renewable Energy Sources

(20 Year life, 7% Discount Rate)

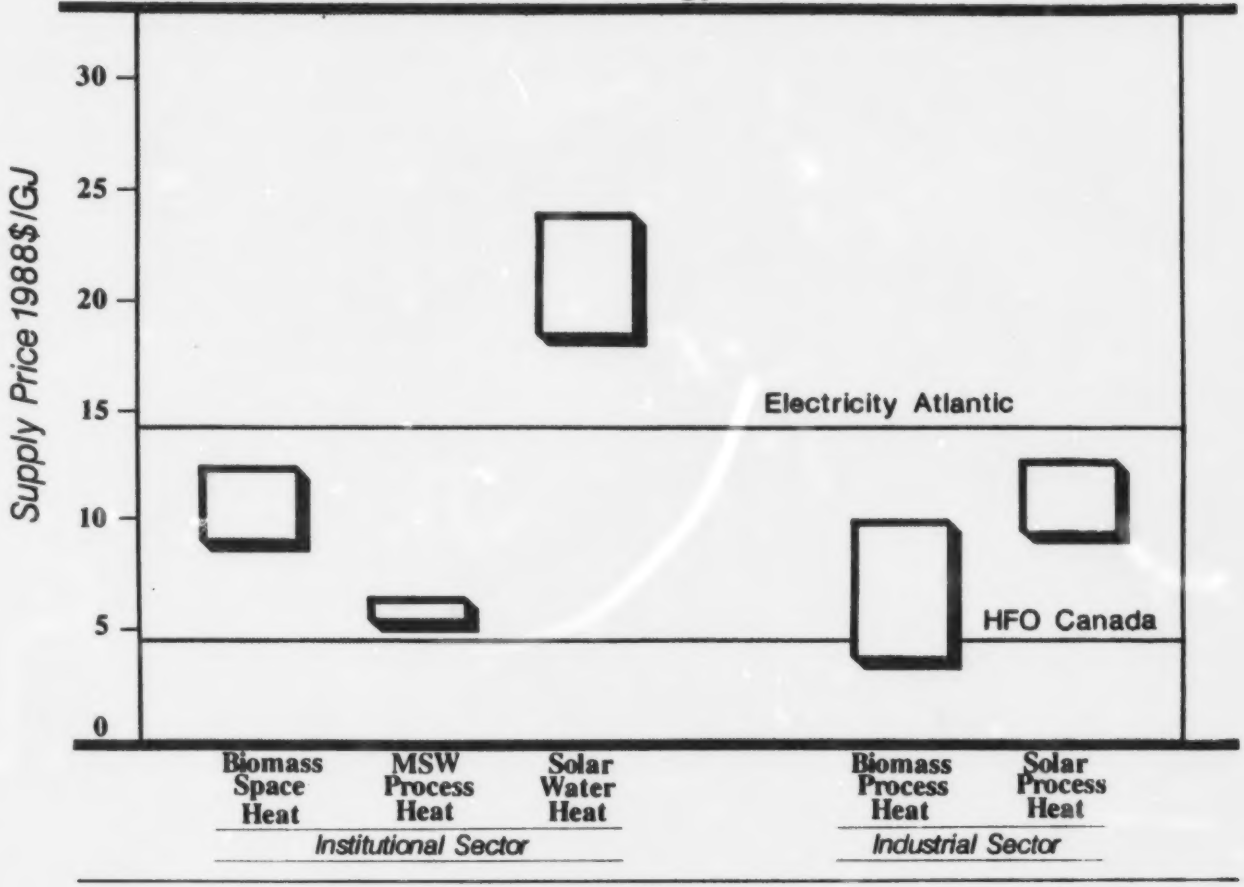


Fig. 4

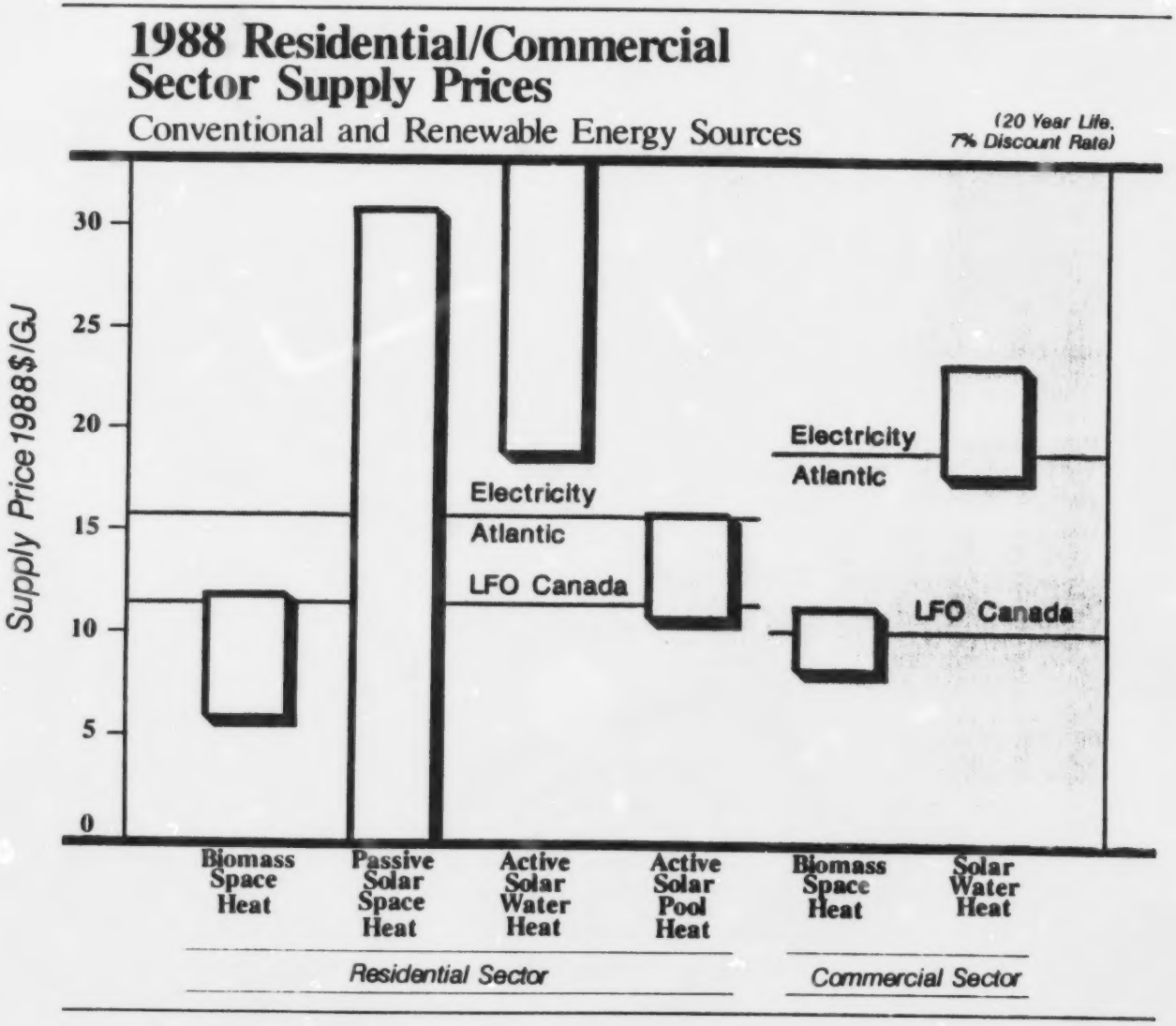

1988 Residential/Commercial Sector Supply Prices
Conventional and Renewable Energy Sources
(20 Year Life, 7% Discount Rate)
Supply Price 1988$/GJ
30
25
20
15
10
5
0
Electricity
Atlantic
LFO Canada
Electricity
Atlantic
LFO Canada
Biomass Space Heat
Passive Solar Space Heat
Active Solar Water Heat
Active Solar Pool Heat
Biomass Space Heat
Solar Water Heat
Residential Sector
Commercial Sector

Fig. 4 (Cont'd)

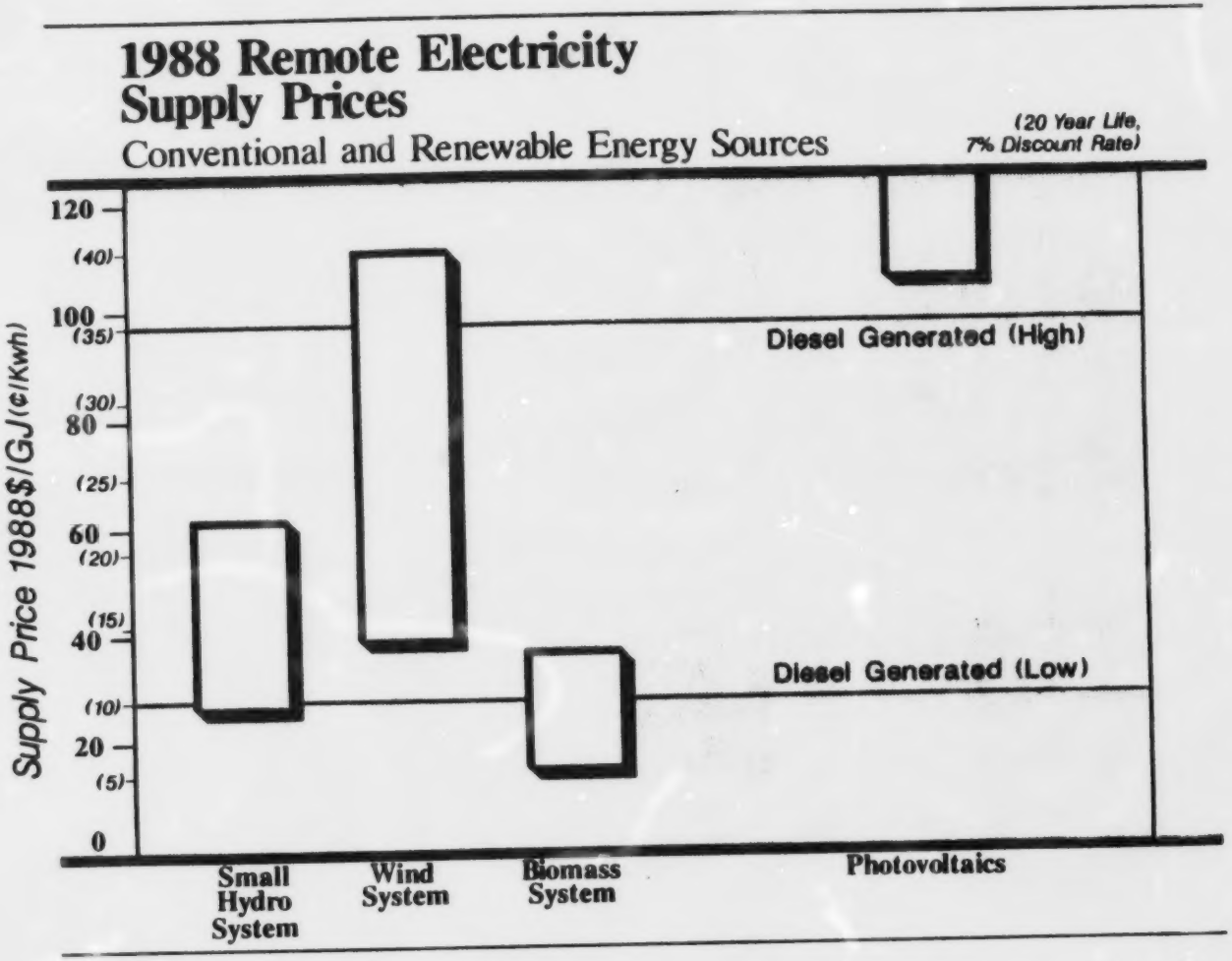

1988 Remote Electricity Supply Prices
Conventional and Renewable Energy Sources
(20 Year Life, 7% Discount Rate)
Supply Price 1988$/GJ (¢/Kwh)
120
(40)
100
(35)
(30)
80
(25)
60
(20)
(15)
40
(10)
20
(5)
0
Diesel Generated (High)
Diesel Generated (Low)
Small Hydro System
Wind System
Biomass System
Photovoltaics

Fig. 4 (Cont'd)

Current Economic Potential for Bioenergy

1988–2005 Energy Price Forecast

($ 1988; 7%; 20 years) 1988–2005

Sector/Application	Current Contribution (PJ)	1988 TECHNOLOGY COSTS Remaining Potential (PJ)	2000 TECHNOLOGY COSTS Additional Potential (PJ)
Residential Space Heat	170	30	–
Forest Ind Pt	252	–	–
Forest Ind Wood Waste	113	31	–
Comm Inst Ind Wood Heat	3.2	13	16
Municipal Waste	4.0	20	32
Liquid Fuels From Biomass	0.2	–	32
Cogeneration - Wood	1.7	17	5
0 25 50 75 100 Penetration(%)	544.1 (83)*	111.0 (17)*	85.0 (13)*

*(MBOE/yr)

Fig. 5

MAINE - TEN YEARS' DEVELOPMENT

Michael Cyr

Marketree

(Manuscript Not Available For This
Illustrated Presentation)

CURRENT ACTIVITY IN WOOD CHIP COMBUSTION SYSTEMS IN THE ATLANTIC REGION

R.J. Brandon

P.E.I. Energy Corporation

Introduction

Being a well forested area of Canada with a significant wood products industry, the Atlantic region has always been interested in the use of wood as fuel, particularly roundwood use in the rural residential sector. The development of activity in the small industrial, commercial and institutional sector was spurred by the first and second OPEC oil shocks. It could be said that the National Energy Program, which responded to those events, probably on balance retarded the growth of wood fuel by shielding users from the full increase in oil fuel prices. However, federal grant programs arising from the National Energy Program, did assist in the majority of the installations that have been put in place over the last six to eight years.

This paper attempts to review the activity in the use of wood chip fuel in medium sized installations that installed heating systems from 200 kw (20 bhp) to 20,000 kw (2,000 bhp). Thus the many smaller installations in each province which did convert to wood fuel have been excluded, primarily due to lack of information. The large pulp and paper residue fuel boilers have also been excluded because they form another distinct market segment.

Nova Scotia

One of the earliest large installations in the province was Gordon's Greenhouses at Oxford. Over the last eight years that the system has been operational they reportedly used 28,000 green tonnes/year of mill waste. Other industrial sites that had been heavy users of oil, such as A.R. Hemming and Stockdijk Greenhouses also converted to wood fuel as a move essential to their economic survival. Smaller sites such as Scott Farms and Delhaven Farms investigated the market to find equipment suitable for their smaller sized operations. This was only available from Europe or in some cases, copies of equipment were manufactured locally. In 1982-83 some smaller installations of 200-300 kw were installed in farms and small businesses. A list of Nova Scotia sites is shown in Table 1.

An explanation of how the 1988$/kwh figure listed in Table 1 is calculated, is given in Section 6.2.

Just prior to the oil price collapse, provincial governments in general were responding to an interest from provincially funded institutions such as hospitals and schools to convert to wood fuel. At the same time in Nova Scotia the Forest Products Association was becoming active in promoting the concept of wood chip combustion in new provincial institutions such as the Nova Scotia Nautical Institute, the Nova Scotia Agricultural College and the Canso Regional Vocational School. The provincial government also sponsored two wood chip supply operations. One of these, Barrett

Enterprises Ltd., is supplying Avon Valley Greenhouses with wood chips.

With the decline of oil prices, the economics of heat only plants appears poor without capital assistance, although for new provincial buildings the comparison is now being made between wood and coal fired electricity rather than imported oil. Currently the provincial government has asked the Public Utilities Board to rule on full avoided cost rate for electricity that would be offered to private power producers. Nova Scotia Power has issued a call for expressions of interest from groups wishing to supply up to 30 MW of of private power. Four or five groups are awaiting the Public Utilities Board ruling before proceeding further with their projects. Another heat only project that is under active consideration is the CFB Base at Cornwallis.

New Brunswick

In New Brunswick conversions to wood chip fuel took a somewhat different route than that of Nova Scotia. Because of different federal grant program guidelines, conversions started later and were co-ordinated as a separate program by the Energy Secretariat, under Ted Owens. A subsidary of ADI Limited, a Fredericton based consulting company, called NorthEast Energy Services acted as a project developer linking low cost mill residue to large institutional users of heat such as the U.N.B. Campus. NorthEast also converted a number of hospitals such as Chatham, St. Stephen and the Victoria Health Centre. Other

provincially funded sites such as Belleisle School used federal grants directly to install equipment. Table 2 lists selected New Brunswick installations. The key installation would appear to be the plant at U.N.B. This installation provided the confidence and developed the expertise that allowed subsequent conversions to proceed. However, it should be noted that the Ranger School in Fredericton has been burning wood chip fuel since 1979 and there was a significant interest in small scale wood chip combustion at U.N.B. from Professors Schneider and Short. A difference between New Brunswick and Nova Scotia is that there have been no large scale private conversions to wood fuel such as Avon Valley or Gordon's Greenhouses. Also, the fuel supplied to these sites with very few exceptions is mill waste from New Brunswick's significant forest products industry. Because of the significant demand from the existing large residue burners at pulp and paper mills, the competition for fuel of this type is somewhat higher than in Nova Scotia. Mill waste fuel costs between $12-$17 per green tonne and whole tree chips $24-$28 per green tonne.

Projects that have been under development and could proceed in the future include the University of Moncton and the two CFB bases at Chatham and Gagetown. As in Nova Scotia, the possibility of supplying wood fuelled electricity is a real possibility and a 25 MW plant at Sussex is under development. This will be a private power development along the lines of similar plants developed in Maine.

Prince Edward Island

In Prince Edward Island a Provincial Crown Corporation was given the mandate in 1978 to co-ordinate all provincial initiatives as regards alternative energy projects. In some ways the P.E.I. Energy Corporation has carried out a similar role to that served by NorthEast Energy Services and the Energy Secretariat in New Brunswick. The first wood energy conversion in 1982 was the installation of a 900 kw unit at the Kings County Memorial Hospital. This has been followed by a series of installations which are listed in Table 3. New provincially funded buildings such as the Souris Hospital had wood fuelled equipment designed into them from the outset. As in New Brunswick there were very few private sector conversions of any size. A difference from the three other provinces was the fact that P.E.I. had a very small forest products industry and so the development of wood fuel suppliers was necessary. A provincial policy of installing the demand and not subsidizing the fuel price is similar to New Brunswick. New installations coming on stream in the western part of the province are using chipped slabs and sawdust residue as fuel because of the low wood volumes and low oil fuel prices. Wood chip fuel is costing $28-31/tonne and chipped slabs and sawdust $25/tonne at the combustion sites. Because of the fact that large heat loads were not available, the Corporation has developed, over the last four years, the concept of district heating to enable

an economical base load to be developed for the capital intensive wood fired equipment. All the conversions have required significant federal capital subsidy to reduce the payback to acceptable levels.

Projects under consideration include the Eric Found Health Centre in Charlottetown and the combined production of heat and electricity. The concept that seems the most attractive given the wood fuel resource available is a 22 MW combined cycle power plant using a gas turbine and wood fired steam plant. The waste heat from this plant would serve either a new processing plant or a district heating system.

Newfoundland

In retrospect it can be seen that the 1.8 MW installation at the Gander Hospital acted as the foundation for subsequent activities in the province in the same way that the Montague Hospital installation served in Prince Edward Island. There are three large pulp mills in the province and a significant forest products industry, and some of these companies such as Newfoundland Hardwoods have installed wood fuelled equipment. The first wood fired power plant in the region is being installed at Roddickton, a 15 MW installation by Foster Wheeler, that will use 55,000 tonnes of wood fuel per year. A large 3.6 MW plant installation has just been completed by the Western Memorial Hospital which will use about 10,000 tonnes per year. A complete listing of installations is

found in Table 4. Future plans, in common with other provinces, include power generation using the independent private power concept developed in New England. Wood fuel costs appear higher than in other provinces with whole tree chips costing $33-$38/tonne.

Trends and Directions

The following are a number of observations that may prove useful or interesting to decision makers contemplating new or existing projects.

Combustion Systems

There are four active suppliers of medium scaled combustion equipment.

Supplier	Head Office	Manufacturing
Trent	St. John, N.B.	St. John, N.B.
Sylva	Thunder Bay, Ont.	Georgetown, P.E.I.
KMW Inc.	Toronto, Ont..	Toronto, Ont.
Northfab	Stratford, Ont.	Stratford, Ont.

In general, the trend has been towards systems that vary fuel and air flows to match thermal demand rather than on/off auger and fan controls. In the smaller sizes, 200 kw and less, underfeed stokers are offered. For larger sites the trend appears to be towards moving grate systems. These are better suited for residue quality fuel and offer the potential for better efficiency. The problem of after sales service remains an issue although the situation is improving as the

suppliers become more established. Screw conveyors remain the most reliable form of fuel transport although some installations are now being installed with bucket conveyors. In-ground storage with hydraulic scrapes is the most common storage system.

Problems have been encountered on a continual basis with fuel storage with inadequate thought being given to fuel bin design and size. Doors and openings that are too small or bins that cannot handle commonly available fuel supply trucks are a continuing problem. Especially with new construction, the expenditure of capital dollars on the boiler room and storage has in general been driven by excessive concern over appearance.

Capital Costs

An attempt was made to determine if a reduction in capital cost over time on a $/kw basis has been made. Capital costs were brought forward to 1988 by using an average inflation rate of 6%. Then this capital cost was divided by the installed capacity. The results from all provinces are shown in Figure 1. The expected economy of scale trend is shown but there is significant scatter in the data. However, when sites where the installation cost is well known are considered, there does appear to be a clear improvement as shown in Table 5.

Table 5

Cost Reduction Over Time

Site	KW	Years of Operation	Capital Cost	1988$/KW
Kings County Memorial Hosp.	900	6	$413,000	651
Chatham	1000	2	$440,000	494
Three Oaks School	800	Startup '88	$310,000	388

Concepts that have been advanced to reduce costs include standardization of systems to reduce manufacturing costs and concentration on the reduction of non-essential costs associated with the building and storage silo.

Wood Fuel Supply

In today's era of low oil prices, the requirement to reduce fuel costs is paramount. Competition from other forest sectors for wood residue is increasing the cost and its quality and availability vary widely. In areas where there is an existing forest products industry, wood fuel supply acts as a market opportunity for sawmills and other forest operators. Where whole tree wood chip supply is available, the experience has been that drum-type chippers produce better quality fuel than disc type chippers and that the container type of fuel delivery system seems to offer a practical transportation system between the chipping and the combustion sites. Most of the combustion equipment put in two to four years ago has

difficulty handling residue at full boiler output so some sites accept supply from both wood chip and mill residue sources. Delivered prices for whole tree chips appear to range from $24 to $34/tonne while mill residue is in the $15-$18/tonne range and mixtures of slab chips and residue cost in the $20-$25/tonne range.

Electrical Power Production

With capital investment now underway for new power production facilities in all four Atlantic Provinces, the possibility of a small portion of this being wood fired is being actively looked at and encouraged by all provincial governments. The small size of the woodfired plant has to be compensated by innovative design and wherever possible a profitable use of the low grade heat. Where there exists a significant forest products industry, the best economic use of the fibre or residue has to be considered since the electric power process is only 30-35% thermally efficient.

Environmental Aspects

There is no doubt that in the next few years the environmental advantages that wood fuel has over other combustion fuels will have to be considered by decision-makers as a consideration. This is especially true with regard to SO_2 and CO_2 emissions. The question of whether to retrofit aging coal fired plants with pollution control equipment or

invest the capital in wood fired equipment needs to be analysed. The justification for capital investment into scrubbers for new coal-fired plants or incremental investment in wood fired equipment will need to be considered.

Conclusion

This paper has shown that improvements have been made in the installed capital cost for wood fired equipment over the last several years in the Atlantic Provinces. Future conversions will depend, of course, on expectations of future oil prices. However, new opportunities exist in electric power generation and cogeneration. Also, there still exists some economic opportunities where residue fuel is available at reasonable cost. In particular, governments and their agencies must continue to try and reduce the capital cost of institutional installations by learning from the lessons of past projects since these high costs will serve to further discourage future installations.

Contributing Authors:

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TABLE 1

NOVA SCOTIA

SITE	SIZE (KW)	CAPITAL COST $ x 1000	YEARS IN OPERATION	1988$/KW	Annual Fuel (Tonnes)Consumption	Fuel Type
VALLEY						
-Britex	6,000	800	2	150	5,500	Chips
-Avon Valley Greenhouses	8,800	973	4	140	15,000	Chips/Mill waste
-Digby School	300	-	Startup '88	-	600(e)	Chipped slabs
-Delhaven Farm	300	45(e)	5	200	250	Chips/Mill waste
-Scott Farms	00	145(e)	6	90	3,500	Mill waste
-Pierek	200	66	5	440	550	Mill waste
-Valley Hosp.	2,000	-	Startup '89	-	4,200	Chips
CENTRAL						
-Canexel	8,100	1,400	1	180	15,000 ODT	Sander dust
-South Shore Reg.Hospital	1,000	-	Startup '88		1,950(e)	Mill waste
-Millwood School	400	-	Startup '88/'89		700(e)	-
-A.R.Hemming	200	29	7	218	-	Off cuts
-Gordon's Greenhouses	13,400	1,200	8	142	28,000	Mill waste
-Stockdijk's Greenhouses	2,200	200	7	137	2,250	Mill waste
-Sunset Adult Res.Centre	400	170	2	480	900	Chips
-N.S.Ag.Coll.	3,000	1,132	Startup '88	380	7,300(e)	-
-Forest Nursery & Ed.Complex	1,200	-	Startup '88	-	1,300(e)	
-Swedwood	1,700	250	1	156	-	Plant waste
EASTERN						
-NS Naut.Inst.	800	-	Startup '88	-	1,350(e)	Mill waste/Chips
-Canso Reg. Voc.School	1,200	-	Startup '89	-	2,300(e)	Mill waste/Chips

[redacted] = [redacted]mat[redacted]

TABLE 2

NEW BRUNSWICK

SITE	SIZE (KW)	CAPITAL COST $ x 1000	YEARS IN OPERATION	1988$/KW	Annual Fuel (Tonnes)Consumption	Fuel Type
Univ. of NB	12,000	2,400	4	252	35,000	Mill Waste
Chatham Hosp.	1,000	440	2	494	3,400	Mill Waste
St.Stephen Hosp.	600	365	2	684	2,550	Mill Waste
Victoria Health Centre	1,000	410	3	488	4,300	Mill Waste
Chaleur Hosp.	3,000	980	1	346	5,300	Mill Waste
College St. Louis Mallet	4,500	-	4	-	2,700	Mill Waste
Bellelsle School	300	135	4	568	550	Mill Waste
H.John Flemming Forestry Centre	2,000	1,500(a)	1	795	5,000	Whole tree chips
St.Hilaire	500	269	4	679	550	Mill Waste
Brookdale	2,500	87	5	47	2,500	Mill Waste

(a) Capital cost includes 2 oil boilers, cost breakdown not available.

TABLE 3

PRINCE EDWARD ISLAND

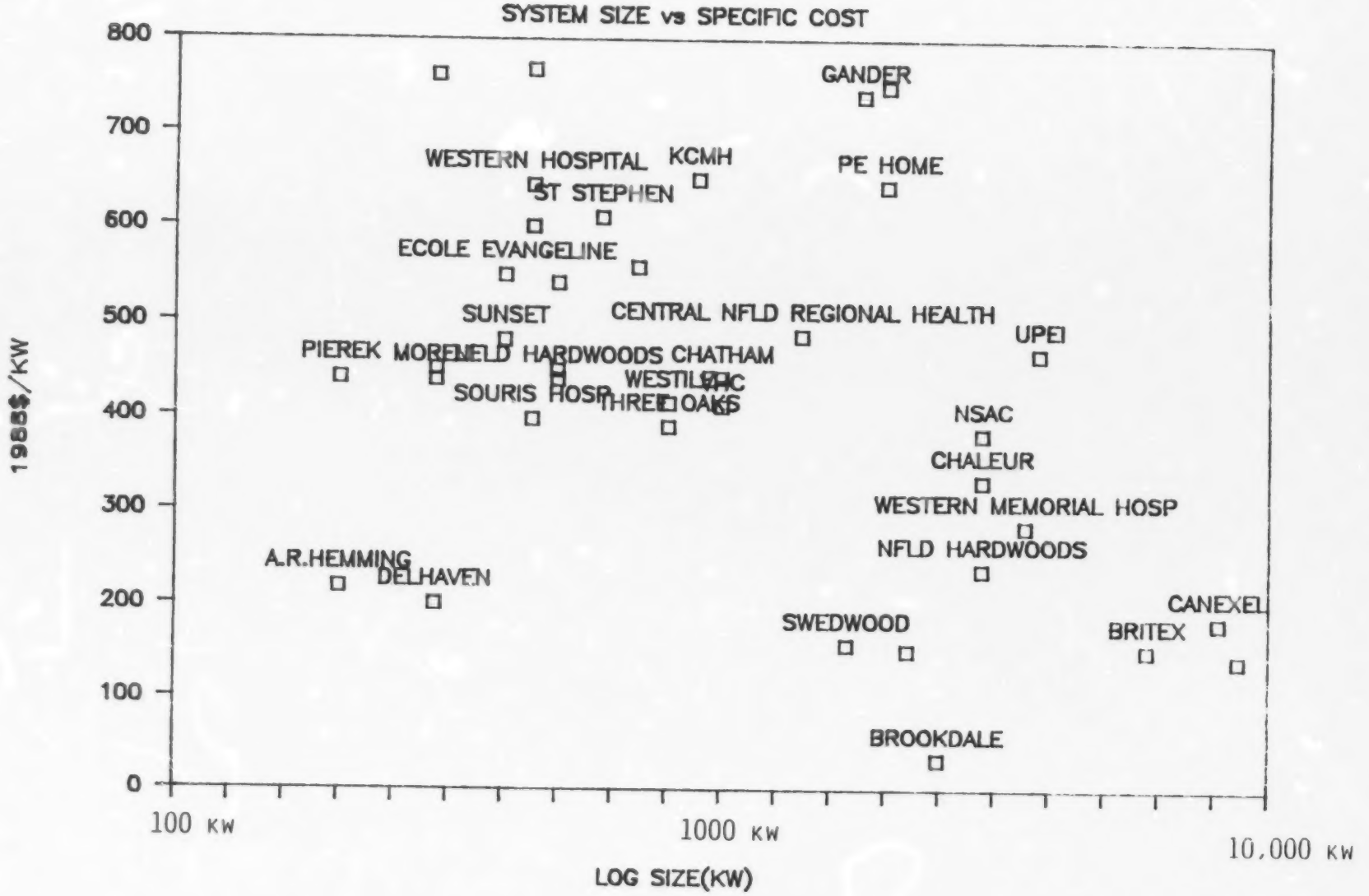
SITE	SIZE (KW)	CAPITAL COST ($ x 1000)	YEARS IN OPERATION	1988$/KW	ANNUAL FUEL CONSUMPTION (tonnes)	FUEL TYPE
University of P.E.I.	3,800	1,580	2	465	5,800	Chips
P.E.Home	2,000	1,150	3	644	3,900	Chips
Kings County Memorial Hosp.	900	413	6	651	1,800	Chips
Montague Jr.& Sr.H.Schools	700	368	1	557	600	Chips
Souris Jr.& El.Schools	500	200	2	448	500	Chips
Souris Hos·.	450	178	Startup '88	396	-	Chips
Morell H.School	300	124	1	438	300	Chips
Beach Grove Home	700	243	2	390	470	Chips
PEI Corr.Centre	400	155	3	462	240	Chips
Wedgewood Manor	400	120	3	357	560	Chips
Three Oaks Sr. High School	800	310	Startup '88	388	800(e)	Chipped slabs/sawdust
O'Leary El.School & Comm.Hospital	450	345	Startup '88	767	550(e)	"
Ecole d'Evangeline	400	174	4	549	500	"
Hernewood Jr.HS	450	270	Startup '88	600	600(e)	"
Westisle School	800	330	Startup '88	413	880(e)	"
Western Hosp.	450	290	Startup '88	644	710(e)	"
M.E.Callaghan High School	450	270	Startup '88	600	710(e)	"

TABLE 4

NEWFOUNDLAND

SITE	SIZE (KW)	CAPITAL COST $x1000	YEARS IN OPERATION	1988$/KW	ANNUAL FUEL (TONNES)CONSUMPTION	FUEL TYPE
Gander Hospital	1800	995	5	740	3,000	Chips
NFLD Hardwoods	3000	560	4	236	4,000	Chips
Clarenville Comm.College	300	192	3	762	480	Chips
Western Mem.Hosp. (Cornerbrook)	3600	1015	1988 Startup	282	10,000(e)	Chips
Central Nfld. Reg.Health Care (Grand Falls)	1400	680	1988 Startup	485	4,850	Chips
Roddickton Power Plant	15000 (elec.)	17000	1989 Startup		30,000	Chips
					15,000	Chips
					10,000	Residue
Superior Logging	1500	-	1		23,000	Residue
Nfld.Hardwood	500	195	2	438	550	Residue

FIGURE 1


SYSTEM SIZE vs SPECIFIC COST
800
700
600
500
400
300
200
100
0
1988$/KW
GANDER
WESTERN HOSPITAL
KCMH
PE HOME
ST STEPHEN
ECOLE EVANGELINE
SUNSET
CENTRAL NFLD REGIONAL HEALTH
UPEI
PIEREK
MORENELD HARDWOODS
CHATHAM
WESTIL
SOURIS HOSP
THREE OAKS
NSAC
CHALEUR
WESTERN MEMORIAL HOSP
NFLD HARDWOODS
A.R.HEMMING
DELHAVEN
CANEXEL
SWEDWOOD
BRITEX
BROOKDALE
100 KW
1000 KW
10,000 KW
LOG SIZE(KW)

TOURS

GREEN - A visit was made to the fuel preparation site of Devon Lumber Co. at Fredericton en route to the chipping operation near Taymouth. Devon Lumber Co. is the major supplier of fuel for four combustion systems in the province including the University of New Brunswick, the largest non-industrial facility in New Brunswick.

The chipping demonstration featured a Morbark 22 and tractor trailers. The chips were produced from cold decks at roadside, the result of full tree harvesting during the summer. Both softwood and hardwood were harvested and piled separately with the hardwood only being chipped. In all instances quality material in the form of logs or bolts is directed to appropriate mills while the lower quality and unmerchantable material is chipped.

The tour concluded with a visit to the wood yard and stationary chipper of the Maritime Forest Ranger School.

RED - Three sites were included in the tour of heating plants, the first being the Victoria Health Centre. The combustion system is a KMW Energy Systems Inc. 100 h.p. boiler producing 3000 lbs./hr steam. It has been operational since 1985 and supplies heat to a nursing home and ancillary community services. The facility annually uses 2000 dry tonnes of processed sawmill residue supplied by Devon Lumber Co. A back-up boiler fired with #2 oil is used for peak heat needs.

The second visit was to the University of New Brunswick central steam plant which supplies heat to the U.N.B. - St. Thomas University campus, the Dr. Everett Chalmers Hospital, two apartment buildings, Research and Productivity Council and the Soils Laboratory of DNRE. A Babcock & Wilcox boiler producing 40,000 lbs./hr of steam is base-loaded to provide 65% of the system heat needs; two oil-fired boilers using bunker fuel are the back-up for peak loads or when the wood-fired boiler is down for maintenance. The average yearly wood residue supply is 21,000 dry tonnes and is delivered by Devon Lumber Co.

The third visit was to the heating plant of the Hugh John Flemming Forestry Centre which has a 200 hp Matheson boiler producing 6000 lbs./hr of steam for 350,000 sq. ft. of the occupied area of the Centre. The facility was installed in 1986 and currently uses 2300 dry tonnes of chipped roundwood annually. The fuel is culled hardwood and softwood from the adjacent University of New Brunswick forest. The oil-fired Volcano boilers back up the wood-fired system and use #2 oil. This visit was completed with a tour of the wood yard, the stationary chipper and chip storage shed.

EXHIBITS

An exhibit of selective equipment and services was set up in the foyer of the H.J.F.F. Centre and was opened officially following the Tours. A reception was held at this time as well.

SESSION "B"

Moderator: R.S. MacLaggan, Consultant

1. SOCIO-ECONOMIC BENEFITS OF WOOD ENERGY
   Dr. Colin B. High, Resource Systems Group

2. FOREST MANAGEMENT IMPLICATIONS OF WOOD ENERGY
   Dr. Gordon Baskerville, University of New Brunswick

3. FINANCING OPTIONS
   J.R. Dean, ADI Group

4. DESIGN AND OPERATION OF A 7.2 MW WOOD WASTE CO-GENERATION PLANT - A CASE HISTORY
   Peter Golobic, Ontario Ministry of Energy
   Paul Shervill, Ontario Ministry of Energy
   William P. Ivey, Chapleau Cogeneration Limited

THE SOCIO-ECONOMIC IMPACT OF WOOD ENERGY USE IN THE PROVINCE OF NEW BRUNSWICK

Colin J. High

Resource Systems Group

Background

Wood was once the predominant fuel in all sectors of the North American economy powering industry, fueling railroads and heating homes. From about 1870 onwards it declined in relative importance as coal, oil and hydroelectric power brought more convenient, more flexible and eventually cheaper energy to industrial and residential users. The rapid increases in oil prices that occurred in the 1970's brought about a re-evaluation of wood energy in several sectors of the economy which resulted in a sharp increase in wood energy use in the forest products industries and in the residential sector. In the northeastern and southern United States and some parts of Canada, wood energy use has also grown in non-forest products industries and in commercial, institutional and utility applications but in New Brunswick wood energy use has been concentrated in the forest products industries and in private homes. Wood fuel use has remained strong in those two sectors, even after the declines in oil prices that occurred in the mid 1980's.

In areas such as New Brunswick, where the forest resource is important to the economy, the effects of wood energy developments on the economy and on the forest resource base have been widely recognized. Compared with using oil or

coal from outside the province, wood fuel creates more jobs and income in New Brunswick and has the potential for assisting in the improvement of the province's timberlands and facilitating additional harvesting of forest products in otherwise economically unpromising locations. Although these economic benefits are widely recognized in Canada and the U.S. there have been only a few attempts to quantify these impacts and to compare them with other fuels. (Chamberlin and High, 1986, Economic Research Associates, 1985, Neill and Gunter, 1987). Quantification of the economic benefits of wood energy has become more important, now that oil prices have declined and the financial advantages of wood energy are less compelling, because government will need to assess these benefits carefully before deciding if or how it should encourage additional wood fuel use.

The socio-economic impacts of wood energy use should not be assessed in isolation but should always be compared with both other energy alternatives and with other possible uses of the wood. Many of the beneficial impacts of wood fuel use in improving the forest, facilitating the harvesting of other products and generating jobs in the forest and transportation industries would also be created by the harvest and sale of the same wood for other purposes. The use of wood for fuel, if it could actually be sold for pulp timber or other purposes, may result in comparatively fewer economic benefits. However, this is unlikely to occur in the present market. It should also be

noted that the use of fuel wood displaces other fuels, such as oil or in some applications, coal, which also create economic benefits in the community. Therefore, wood fuel economic impacts should be assessed alongside the impacts of the fuels that wood replaces, so that the net effect can be seen.

Socio-Economic Impacts of Wood Energy Use

The socio-economic impacts of wood energy are quite diverse and include the full spectrum of direct and indirect social and economic effects. This ranges from all the effects in harvesting, transportation and handling of wood, to the construction and operation of wood fired facilities, from electric power plants to home wood stoves. The impacts include direct employment and income associated with wood energy activities and indirect impacts from purchasing goods and services by the plant owners and by their employees. Wood energy, like all economic activities creates a multiplier effect which spreads the impacts through both the local community and the wider economic system. Socio-economic impact analysis includes a consideration of social effects such as changes in community structure resulting from increases in employment, effects on schools and community services, and other less tangible effects such as self-sufficiency and community pride. In practice, however, such social impacts are very hard to quantify. Economic impact analysis is usually quantitative and tries to place real dollar values on the

effects. It differs from financial feasibility analysis which is usually undertaken by a project developer because economic impact analysis is not especially concerned with the revenue and expenditure streams of owners, but instead looks at particular projects or programmatic activities from the perspective of a defined community or society at large. Thus many of the costs and benefits of wood energy which are external to the specific project are of prime concern in community or province-wide socio-economic impact analysis.

The Wood Energy Industry

The wood energy industry can be considered in two parts: the wood fuel supply and transportation sector, and the facilities sector. The wood fuel supply and transportation sector includes the supply of wood from residues from existing manufacturing as well as the harvest and transportation of wood from the forest. Manufacturing residues are generally lower-cost and create fewer jobs and income than harvesting wood. However, the potential for growth in the use of manufacturing residues is quite limited. The economic impacts of wood fuel supply are generally similar for all industrial and commercial applications of wood energy that use chips or hogged fuel. Impacts for residential wood fuel supplies which use logs are different, largely because supplying logs is more labour intensive. The major job categories of the wood fuel supply sector are given in Table 1 below.

Table 1

Wood Energy Employment Categories

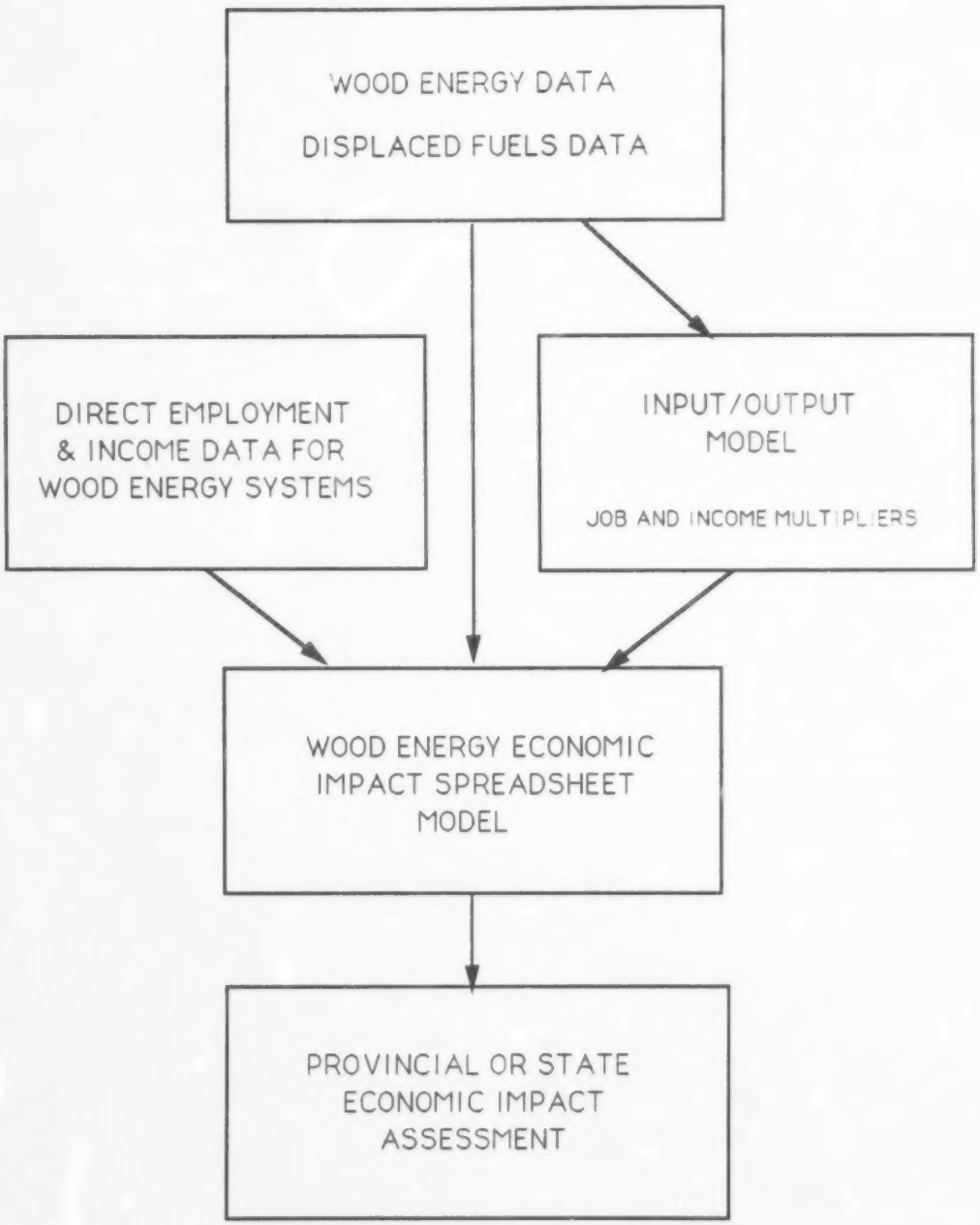
Component	Industrial/Commercial	Residential
Harvest & fuel supply	Whole tree chipping operators, loggers & foresters	Loggers, firewood dealers & foresters
Transport	Chip & mill residue truckers	Firewood truckers
End use Operations	Wood appliance mfg. Wood appliance retailers, installers and chimney sweeps	Boiler construction Plant operators Wood handlers Main. personnel.

The wood fuel supply sector impacts are generally larger than the wood energy facilities sector and wood fuel supply creates more provincial level jobs and income than supplying the same amount of energy from conventional fuel. Industrial wood energy facilities are similar to comparably sized fossil fuel facilities except that they are generally slightly larger and more costly because the fuel has a lower heat value per tonne and is more difficult to handle. Environmental controls are more complex and expensive than oil, but usually less complex than in coal plants. Overall, wood fired boilers and electric power plants create slightly more jobs and income than comparable fossil-fueled plants precisely because they are more expensive to build and maintain.

Methodology for Assessing the Economic Impact of Wood Energy Use

In theory, there are several ways in which the economic impact of wood energy could be evaluated. However, the most practical and comprehensive method is to use the hybrid model approach. This combines the use of survey techniques and detailed engineering studies to obtain the direct expenditures and employment in each wood energy sector with the use of input/output models to determine the indirect and induced effects on the provincial economy. This approach is shown in figure 1. For the studies which I recently completed on the impacts of a 25 MW wood-fired electric power plant in Sussex, New Brunswick, I used the Statistics Canada input/output model of the provincial economy to determine the indirect and induced impacts while relying on detailed engineering studies by Neill and Gunter Ltd. for the direct expenditures in constructing and operating the plant. In assessing the economic impacts of the displacement of equivalent energy capacity, I used data provided by New Brunswick Electric Power Commission for the direct expenditure on construction and operation of a prorated share of a larger coal-fired electric power plant fueled by either New Brunswick coal or imported coal. Again, indirect and induced impacts of the equivalent coal-fired capacity were determined by reference to the input/output model. Like all input/output-model-based analysis, this study assumes that the incremental change in

STRUCTURE OF THE ANALYSIS
ECONOMIC IMPACT OF WOOD ENERGY


WOOD ENERGY DATA
DISPLACED FUELS DATA
DIRECT EMPLOYMENT & INCOME DATA FOR WOOD ENERGY SYSTEMS
INPUT/OUTPUT MODEL
JOB AND INCOME MULTIPLIERS
WOOD ENERGY ECONOMIC IMPACT SPREADSHEET MODEL
PROVINCIAL OR STATE ECONOMIC IMPACT ASSESSMENT

jobs and income associated with additional wood energy use is essentially linear. The analysis is also based on the last revision of the national and provincial input/output tables, which was made in 1979. Although due allowance has been made for inflation and technological change in the wood energy industry, no allowance can be made for any structural or efficiency changes which may have occurred in the provincial economy since 1979. This is an important limitation, because there have been significant changes in energy-related industries in recent years. The use of industry-specific expenditures in the wood energy sector to some extent offsets these problems and certainly provides a more reliable assessment of wood energy impacts than would reliance on a pure input/output approach.

Comparison of Economic Impacts

An accurate assessment of the economic effects of wood energy requires that we assess the employment, income and other economic effects of wood, alongside the fuels that it will be most likely to replace. For example, as can be seen in table 2, the jobs and income generated in New Brunswick by a 25 MW wood-fired electric power plant are considerably higher than for an equivalent amount of power produced either with New Brunswick or imported coal. However, the differences are greater when compared with a plant fired by imported coal. It is important to make realistic assumptions about the size of the plants compared. In this case a 25 MW wood-fired plant was

compared with a 25 MW share in a 400 MW coal plant. Both of these sizes being best suited to the actual conditions prevailing in the province.

Table 2

Economic Impacts of a Wood-Fired Electric Power

25 MW Plant Capacity

Economic Impact	Wood-Fired	N.B. Coal Fired	Imported Coal-Fired
Total N.B. Jobs	252	88	11
Total N.B. Income	$14,296	$4,313	$756

*Note: Jobs are full-time equivalents and income is in thousands of 1992 dollars per year.

The very marked differences between the impacts of wood-fired and coal-fired facilities, especially when wood is compared with imported coal, occur largely because a greater proportion of the wood income stays in the province and in consequence generates more jobs in the province. When viewed from the provincial perspective this makes wood fuel beneficial. In this case however, no account is taken of the relative cost of the fuels to the consumer. These differences may themselves have significant economic impacts, depending on which fuel is chosen, and the cost of the fuels that are replaced. In the case of the twelve northeastern states of the U.S.A. it was found that in 1985, when oil prices were very high, the economic benefits of the savings from using wood for fuel exceeded the sum of all the other direct and indirect

benefits. (Chamberlin and High, 1986). If, on the other hand, wood is used for fuel even though it is more expensive, then that additional cost must be compared with the economic benefits.

It is quite interesting to compare the economic impacts of industrial wood energy use in New Brunswick with those in other areas. Unfortunately there are not any comparable studies available for nearby Canadian provinces, but we can make some comparisons with New England states. Table 3 compares the jobs and income associated with the burning of 1000 tonnes of wood for industrial energy in the three northern New England states with an estimate for equivalent use in New Brunswick, based on the data from the Sussex study (Neill and Gunter, 1987).

Table 3

Economic Impact of Industrial Wood Burning

In New Brunswick and Northern New England

	Jobs per 1000 tonnes	Income per 1000 tonnes
New Brunswick	0.7	$29,256
Maine	1.6	$40,399
New Hampshire	1.5	$36,973
Vermont	1.5	$29,217

*Note: Jobs and income are gross without accounting for displacement, savings or losses when compared with other fuels. They include both direct and indirect effects. Income is state or provincial only in 1987 Canadian Dollars. Source of data Chamberlin and High, 1986 and Neill and Gunter 1987.

It can be seen from table 3 that the provincial income per 1000 tonnes of wood fuel burned for industrial purposes is similar to the comparable state incomes in northern New England. The employment however, is notably lower in New Brunswick. These income estimates for New England states are based on the actual mix of industrial wood energy facilities existing in the states in 1985, whereas the estimates for New Brunswick are based on the Neill and Gunter study of a single new wood-fired electric power plant. It is perfectly possible that if there were data on the complete range of industrial facilities in New Brunswick then the jobs estimates may be much closer. Another useful comparison that can be made is the ratio of indirect to direct jobs which indicates the multiplier effect that wood energy has in the community. In New Brunswick, again based on the Neill and Gunter (1987) study, the indirect/direct job ratio was 1.7 whereas the comparable ratio for all industrial wood energy in Maine was 2.8. (Chamberlin and High, 1986). This difference may be accounted for by the larger size of the Maine economy and by the fact that we are comparing all industrial wood energy systems in Maine with a single steam-electric system in New Brunswick

Overall, the studies completed in New Brunswick to date generally confirm the widely held view that wood energy has substantial beneficial income and employment impacts in the province. These impacts are broadly comparable with those studied in detail in the New England states after savings

benefits, which were substantial in 1985, have been excluded. Even though wood energy is less economically attractive today than it was when oil prices were higher, the economic benefits, especially in areas of high unemployment, are still substantial and quantitative evaluation of these benefits can be a valuable tool for public policy makers.

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FOREST MANAGEMENT IMPLICATIONS OF WOOD ENERGY

Gordon Baskerville

University of New Brunswick

It is a truism in forestry that markets must exist before forest management is possible, and a continuing lament is "if only there was a market for the low quality material". Such markets would make it possible to harvest in a manner that balanced the drain and growth of quality material. Such markets would make silviculture easier, and generally facilitate enhancement of forests. With wood energy, it finally looks like there will be a market for material that has posed a perennial forest management problem. Therefore we can look forward to great strides towards management of the forests--or can we?

The message of this paper is a mixed one, because there must be mixed feelings about what markets opened by wood energy can do for forest management as it occurs, or does not occur, in the forest. There is an emerging need for a cost-efficient supply of raw material for wood energy, and this is opening new markets for otherwise unusable wood material. Any policy relating to the use of wood for energy will be appropriately couched in terms of the proverbial "sound management", and concern should be not for what is said with respect to wood energy, so much as for what actually happens in the forest.

Wood energy is a veritable two-edged sword. Wood energy presents a situation that finally could be the making of

forest management in New Brunswick, or wood energy could be the vehicle for ultimate destruction of quality in the forests. This is not a problem inherent to wood energy, rather the paradox lies in the way people will react to the markets opened by the advent of wood energy. Those actions, not the associated words, will determine the impact of wood energy on forest management.

Wood energy has become a now item in our society. That means it is a good thing to talk about and, as a sign of the times, it also means it is talked about in loose terms. It is easy to say wood energy will be good for forest management. It is difficult to make wood energy good for forest management as that is realized in the forest over time.

Wood energy certainly will be good for wood markets in New Brunswick--I am yet to be convinced wood energy will be good for forest management. The potential is there for the new markets to accelerate the installation of management that is already occurring in some of the forests, and to motivate towards management of other forests. However, potential must be one of the most damning words in the English language.

This paper will sketch the problem in quality in New Brunswick forests briefly, and then describe three possible futures for these forests. These are reasonably possible futures that could be made to happen. While in large part the future happens to us, our actions have considerable influence

on how the future happens to us. This influence is exerted by the choices we make, and the actions in the forest that follow those choices, as the future unfolds day by day.

Where Are We Coming From?

Because of its long-lived nature the forest retains a record of choices made by generations of man. That record should be examined regularly because part of where we are going, is where we are coming from. While New Brunswick has a forest history far too long to cover here, a few points with respect to the major forces will help put the management potential of wood energy in perspective.

It is customary to speak of the role of forests in social development as "illustrious". There were the days of supplying masts for the King's navy, the days of wooden sailing vessels, the days of the lumber boom, and so on. In terms of economic development, the forests certainly have played an illustrious role. There is hardly a community (large or small) in the province that does not have some kind of forest industry as an important element in its background. However, the economic development has been made at the expense of quality in the forests.

It is rare to hear someone speak of current forests as illustrious. It is rare to hear anyone brag that a forest is just what the management efforts of the last four decades aimed to produce. Indeed, if the forests of today were anything like the words in the management plans, the words in the

legislatures, and the words in the kitchens over the past few decades, this symposium would not have taken place. If deeds in the forest had matched words, there would be insufficient waste, and low grade material, in the forests to warrant consideration of wood energy.

The history of New Brunswick is pretty much one of systematic mining in the name of economic development. As early as two centuries ago white pine timber was harvested at a rate that exceeded the ability of the forest to grow white pine timber. This was done in the name of economic growth--job, wages, and community development. Obviously jobs and economic development are essential, but it is also important to be clear about how New Brunswick has used (not managed) its public and private forests to gain jobs and development.

It was possible to balance the harvest of 200-300 year old white pine trees with the 200-300 year replacement rate of such trees. Had that been done, say prior to 150 years ago, there would be 200-300 year old white pine timber around today. Today these trees would not be used for masts, but they certainly would command top prices in contemporary lumber and secondary manufacturing markets. Not only was there a failure to balance the rates of harvest and growth, but when 200-300 year old white pine were in short supply, innovative people found economical ways to harvest and use smaller 100-200 year old trees.

When those younger and smaller trees were in short supply, even younger trees were found to be economical sources of raw material, then different species, then younger and smaller trees of different species, and so on. This was a strategy of achieving economic development based on using the forest. The strategy was outstandingly successful when measured in terms like jobs, wages, taxes, and community development.

Economic and social development was achieved step by step with incremental high-grading of the forests for quality. Quality of the forests has been run down by each incremental step of high-grade harvesting until the quality in the present forests is a pale image of the illustrious past.

Where Are We Today

Are New Brunswickers doing any better today, now that they are wiser from experience? The answer to that question is a live issue in 1988, and the approach taken to wood energy may turn out to be the key. Many still say the forests should be cut selectively so harvests can be made again and again. Despite wide public acceptance as "the answer" there are two fatal flaws with selective harvesting as practised in New Brunswick--indeed in Canada.

First, the harvests are not by the selection method where a stand is culled for the full range of quality, size classes, and age classes. In Canada selective means cut the best and leave the rest. This bears no technical relationship

whatsoever to European selection systems with which the local high-grade harvesting is so frequently compared.

Second, selective high-grade harvests are taken too close together in time to permit stands to recover. Stands are not allowed enough time between harvests to permit them to restore quality. It is always possible to make each successive selective harvest. There are always trees there, but each successive harvest removes raw material of poorer and poorer quality. Without doubt, the worst sylvan slums in New Brunswick have been created in the name of selective harvesting.

Selective harvesting removes the best and leaves the rest, and selective harvesting uses a re-entry time shorter than the regrowth time of the forest. Selective harvesting follows precisely the way an earlier society degraded the ancient forests that are so often held up as illustrious. Selective harvesting is precisely the way the quality in many forests continues to be run down in 1988.

It does not matter if selective means individual stems in a stand, or if selective means select whole stands for clear cutting--if quality material is removed more rapidly than forests grow quality material, the overall quality of the forests will decline continuously with time.

It does not matter what it is called, or how good it is said to be. What counts is what actually happens in each forest. The current forests in New Brunswick are of poor quality relative to the forests of the past because of

selective high-grading. The current forests are of poor quality relative to the capacity of the sites on which they grow because of selective high-grading.

An active well-designed approach to management has been initiated in the Crown forests in the last decade. While it started with forest that were severely degraded, considerable progress has been made. Some say there has been management for a long time, and while that may be, who will agree the forests of today are the target forests for which they have been "managing"? Who will say the present forests are the ones envisioned when management plans were written in post world-war II? Who will agree the present forests are what society expected as result of "management"?

I believe New Brunswick has until recently paid lip service to management of the forests, while high-grading was continued in the name of economic development. For what it is worth, the situation is worse in other jurisdictions, and most do not yet realize the problems they face!

Surely, some have been talking about managing the forests for a long time. But there is little evidence that much of the talk has found its way into action in the forest--at least until recently. While the Crown land situation is frequently commented upon, the problems there are potentially controllable, and are being tackled directly in the forest. The situation in private forests, particularly the woodlot sector, is worse than on Crown land, and, with a handful

of super exceptions, the approach on these ownerships is still heavy to lip service.

The forests of the woodlot sector have been degraded longer and more intensively by selective high-grading than any other forests in the province. In recent decades these forests have not been protected from budworm, resulting in increased harvest pressure, and the present state of quality in these forests is pitiful.

It is difficult to imagine that the present state of either the Crown forests or those in the private sector reflects the intent of all the words about management in recent decades. The words have been great, but until recently actions in the forest did not match up.

Where Can We Go?

In their present state what can the New Brunswick forests produce? This is not the place for a definitive answer to that question, but New Brunswick has the most thorough timber supply analysis of any province in Canada. One of the advantages to being the first to recognize the ultimate necessity of managing a resource, is that you are also the first to acquire the necessary data and skills to manage. A wide array of futures are open for the New Brunswick forests.

The future options are complicated by the fact there is actually an over-supply of both softwood and hardwood right now. The softwood over-supply results from large areas

regenerated by the budworm in 1920's and now all maturing at once, the hardwood over-supply stems from historic high-grading of hardwoods and a general successional trend towards hardwoods replacing themselves, or softwoods, following selective harvest.

There is a current surplus of mature stands and the forests have little area supporting stands one or two decades younger than those currently mature. Removal of the mature stands too rapidly, before the next younger stands are mature, will result in collapse of raw material supply either in volume, or in quality, or in both.

There is no current over-supply of quality raw material in either softwood or hardwood, and quality will decline for the next 30 years, no matter what course is followed. The volume over-supply is of low quality material and is transitory resulting from the century long pace of forest development. In this circumstance removal of the current over-supply must be paced so that it does not simply recreate the present problem for a later generation--with a severe shortage in the intervening years.

The wood supply analyses show current harvest levels are sustainable in terms of volume. The wood supply analyses show current harvest levels are not sustainable in terms of quality of raw material. Quality is still being removed from the forests more rapidly than the forests are able to grow quality. However, with perseverance and a bit of good fortune that should be a temporary condition.

New Brunswick has an approach to managing at least its Crown forests that is aimed at re-establishing quality, but natural biological delays in the system will ensure the problem will become worse before it gets better. It is not possible to fix wood supply problems except by allowing the forest to grow for a few decades. Recovery of quality takes the time to grow quality. While current harvest rates for sawlogs are in excess of the sustainable level, most of the stands being harvested would breakup from overmaturity if they were not harvested. In that context, harvesting them over a period of transition is a sensible action.

There are many paths into the future, each one evolving as a result of choices made as the future unfolds. Three such choices open to New Brunswick are; (1) just letting the future happen, (ii) choosing a future and trying to make it happen, and (iii) choosing a future by words and taking the advantages, while not implementing the necessary actions to control what happens.

Letting The Future Happen

The problem lies in the fact that while the current degraded forests have ample material suitable for wood energy that will not grow into better quality with time, it is also possible to approach harvesting for wood energy by high-grading. While there is currently a surplus of biomass, considerably in excess of what is needed to supply wood energy,

if biomass is harvested on a minimum cost basis without reference to future forest development, the inevitable result will be a degradation of the forests, even as a source for energy.

It is certain that the final cost of producing energy will be lower if the delivered wood cost is minimized by concentrating harvest more on larger trees and whole stands, than on smaller trees and cleanup areas. The way to keep wood energy costs down would be to harvest selectively for lowest cost energy exactly replicating the selective high-grading processes of the past, but with much more devastating final impact. To the extent contemporary greed with respect to the forest resource prevails, the result of wood energy in this context will be a further degradation of the forests.

The degradation will not be immediately apparent, and since the market benefits are immediate this is a tempting option. Without conscious choice, or thought about the future, wood energy could once again lead to incremental high-grading.

Such continuation of high-grading of the resource is the default option. The default option will determine the future forests if there is no clear decision to take one particular action path, ie., if we just let the future happen to us. It is what happens if the classic wait and see attitude prevails.

Making One Future Happen

A second future involves a clear choice to use the new wood energy market as an opportunity to control high-grading, and to control harvesting for wood energy to begin to clean up sylvan slums. This approach would mean higher delivered wood costs and therefore more costly power. This approach would move directly to improve quality in the forests at large by removing low quality selectively, instead of removing high quality selectively.

There is an interesting potential problem associated with this future, in that current availability of low quality material suitable for wood energy might not be sustainable. That is, if a wood energy program were targeted at cleaning up the slums, in time there would be a reduction in the supply of low quality material. That would be a nice problem to have, but of course that will only be a problem if management with respect to wood energy moves from brave words, to action in the forest.

Several points are worth emphasis with respect to the future of using wood energy markets as an opportunity to clean up slum forests:

(1) The amount of surplus biomass (low quality) available for wood energy will not be increased, but will likely be decreased by management over time.

(2) The amount of roundwood available for raw materials like pulp and studwood would be increased gradually over time by management.

(3) The rate of decline in availability of sawlog quality material would be slowed, and eventually turned around by management.

(4) There would be a general shift towards the production of greater quality in the forest.

(5) There is no doubt a balance could be reached where both roundwood production, and wood energy are sustainable in a manner that maintains overall quality in the forest with time, but by its nature this balance will not maximize the production of either wood energy, or high quality material.

The benefits of this choice are available in reality only if wood energy harvesting is used as a management tool to bring slum forests back into production. The benefits are immediate to the extent that harvesting for wood energy is used to recapture some of the productivity lost to past high-grading. This will allow more rapid harvest of existing stands because of more rapid replacement of the slums.

The second alternative is attractive. Better quality material in the long run, and more material in the short run. This second future is not a default option. The second future will not just happen by spending some money to initiate wood energy programs. The second future will only happen if management dollars are spent, if there is strict management control over how the dollars are spent, and if there is management control of harvesting, particularly of harvesting for wood energy.

There Is A Worst Case Scenario

The managed future described above will unfold only if there is a concerted effort to control the implementation of harvesting for wood energy in the context of forest management. That future will not unfold if wood energy is allowed to unravel in the forest as a least cost harvesting approach. A third possible future constitutes a worst case scenario, where the words associated with the second option are loudly spoken, and the benefits of the second option are taken to the maximum extent possible, but the actions associated with the second option are not taken in the forest. An attempt to take the benefits of wood energy markets where forest management control of wood energy is not implemented, will result in unbelievable degradation of the forest. Without real management control in the forests the worst case scenario will unfold no matter how fine the words used to describe the process may be. For the worst case scenario, the wood markets are great in the short term. But without management control, New Brunswick will need to find markets for raw material of lower and lower quality over time.

Choices

There are many forest futures open. The three futures outlined above are easily reachable from where New Brunswick is today. It is possible to;

(1) blunder into the default future and extend historic high-grading to harvesting for wood energy, or

(2) by dint of hard work and real forest management control wood energy can be made a powerful tool for rebuilding quality in the forest, or

(3) a preference for a managed approach can be stated, and increases in harvest rates allowed, but deeds do not match words in the forest thereby lapsing into extreme high-grading.

Choosing to manage the forests is as easy as saying it. Actually managing the forests, is a different thing altogether. Many forest owners (including not incidentally the owners of the public forests) choose management, but very few have the will to implement management in the forest when it becomes apparent that management interferes with maximizing profits from the markets.

For each forest that is actually managed, there must be hundreds that are said to be managed, but which never get there because of owner-response to market pressures. It is a truism that we must have markets to manage, but it is also a truism that while markets exist we must capture a share of them. Management, it is said, will come in good time, once there is sufficient profit from the property. That apparently reasonable argument happens to be the path to continued forest degradation.

There are many futures open to New Brunswick, but the nice comfortable ones where high grading is continued for maximum current economic gain, and the forest is magically fixed by all those federal/provincial dollars do not exist. The problem is not dollars, rather it is the way the forest is harvested. It is not sensible to state a goal and then choose an implementation that is inconsistent with the goal. This is not a problem of "you can't get there from here", but rather "you can't get there by that route".

Conclusion

New Brunswick can have better forests, but there is a price to pay, not just in federal/provincial dollars, but in changing the way the resource is used. The change is fundamental--from using the resource to develop the economy, to managing the resource to manage the economy. Wood energy puts New Brunswick forestry at a classic turning point. There are several futures that can be made to happen with some effort. There is a default future that will unfold if New Brunswick uses wood energy as just one more way to high-grade the forests. There is a future that can be had if wood energy is used as a management tool to upgrade the forests. There is a need to choose a future decisively and to act to make that chosen future happen.

New Brunswick is making gains towards managing its forests, but short term markets still over-ride management.

What is happening in the forest might be termed good stand silviculture, but tentative forest management, and the New Brunswick forest management efforts are as good, or better, than anywhere in Canada. The problem is that it is infinitely easier to talk forest management, than it is to make forest management happen in the forest which is the only place it really counts.

A pessimistic outlook is not warranted, indeed in this line of work one has to believe management will become a common-place reality. At the same time, it is wise to be realistic in that the track record is not encouraging with respect to using new markets as management opportunities, as well as capturing marketing opportunities. The real issue in wood energy will be the degree to which it merely opens another market to motivate exploitation of the forest, vs the degree to which some of the market force is diverted towards improving forest management. If the options are understood, reasonable choices will be made.

Once again, the range of options includes:

(1) an opportunity to use wood energy for short term economic gain while continuing to high-grade the forests and further reduce their quality.

(2) an opportunity to use wood energy harvesting as a management tool for facilitating improvement in the forests.

The first will be good for current wood markets, but devastating to forest management. The second will not be quite so good for current wood markets, but will allow the development of a much longer, and better, market than currently exists.

Wood energy offers a tremendous opportunity to accelerate the introduction of forest management, but real dedication, and will, is required on the part of New Brunswickers.

FINANCING OPTIONS FOR ENERGY PROJECTS

J.R. Dean

The ADI Group of Companies

Introduction

The financing for any project needs careful thought and planning, because financing costs can have a significant impact on the final cost of the project, due to interest during the construction period, and also on the annual operating costs and cash flow due to interest and principal payments. My remarks today are intended to give you a general understanding of the options which may be available for financing energy projects and some of their implications. I will be dealing with broad principles and not attempting to incorporate such things as inflation rates or socio-economic benefits in my discussion.

For governments, hospitals, universities, and similar institutions, the usual approach to finding capital for projects would be by borrowing or debt. In some cases, special funds may be available through private donations or trust funds to reduce the borrowing. Industries also borrow to finance capital projects but will usually provide part of the capital from current or retained earnings or by raising new equity capital.

In the simplest of terms, then the investment criteria for public bodies which were considering a wood-fired plant would be the difference between expected annual savings and the cost of debt (interest and principal repayment). So, if

equipment was to cost $1,000,000 and funds were secured by way of a 10-year loan @ 12% interest with equal annual payments of $177,000, annual net savings should exceed $177,000 to be attractive. The greater the risk of not achieving the savings, the greater would be the required spread between these two numbers.

For the private company, the investment criteria are somewhat more complex because of income tax costs and the need to show a return on the shareholders' equity investment. Taking the same project as before but applying typical private company criteria would require the annual net saving to be increased substantially over the $177,000 as mentioned above. For example, if a simple payout of capital in 3 years were required, the annual savings would have to be greater than $330,000 to be attractive.

There has been a good deal of interest in "non-debt" or "off balance sheet" financing for energy projects in recent years. This began with private companies who, as energy consumers, were convinced that a project was sound and would bring financial rewards but at the same time offered a return on investment which was less than could be made on investments in production equipment. Alternatively for some firms capital funds may have been scarce due to expansion plans or for other reasons, preventing them from investing in the energy project.

More recently, governments as well as schools, hospitals and other public institutions have been attracted to

this type of financing as capital funds became more restricted and operating costs continued to take a greater share of the total funds available.

Before going further with the "off balance sheet" approach, let's look at two of the tax incentives which have been available to manufacturing and processing companies, i.e. accelerted capital cost allowance and investment tax credits.

Conservation and Renewable Energy Equipment is eligible for special tax treatment under Class 34 of the Income Tax Regulations by way of accelerated capital cost allowance. The primary purpose of the equipment must fall within the following:

1. Thermal generation of electricity (steam) (7000 BTU/KWH)
2. To produce heat primarily from natural gas, coal, coal gas, lignite, peat, wood wastes, or municipal wastes or any combination thereof
3. To extract and reuse heat from a thermal waste or from industrial by-product heat
4. Active solar heating system
5. small scale hydro electric generation

Particular note should be taken of 1. and 2. above as they relate to the construction of a wood-fired power station. If the station were installed by a manufacturer or processor to supply steam and power for internal use, i.e. a cogeneration plant, it would be eligible under 1. However, if it were a plant designed to produce and sell power only, the wood

handling, boiler and associated equipment would be eligible under paragraph 2, but the turbine generator and related equipment would not, because the heat rate would be above 7000 BTU/KWH.

This means that for the equipment in a complete wood-fired power plant to be eligible, it must be of the back pressure or non-condensing type as would be used in an industry where there was a large process steam requirement.

Equipment falling within the above definitions may be written off (capital cost allowance) at the rate of

Year 1 - 25%

Year 2 - 50%

Year 3 - 25%

Now what is this benefit worth? Well let's assume that the eligible equipment costs $1,000,000, it has a useful life of 20 years, corporate income tax rate is 25% (small business rate) and interest rates are 12%. The benefit in being able to write the plant off earlier could be expressed as the difference in present worth of capital cost allowance for the two arrangements. These are shown in Table 1.

TABLE 1

TAX SAVINGS DUE TO FAST WRITE-OFF

OF $1,000,000 OF ELIGIBLE EQUIPMENT

Present worth of Tax Savings with Class 34 write-offs	$200,000
Present worth of Tax Savings with normal write offs	150,000
Difference in tax savings	$ 50,000

Please note however that the maximum benefit is only available to a company which is in a taxable position and which has $1,000,000 of taxable income in the first three years of operation. If the user is non-taxable (schools, hospitals, etc.) then there is no taxable benefit. For a more exact treatment of the tax implications of class 34 for your specific operations you should consult your accountant or tax specialist.

Now let's turn our attention to the investment tax credit, (ITC). Here again, this benefit is not available to the non-taxable user.

Basically, the investment tax credit has two components,

1) a refundable portion, if no federal tax is payable or not carried back against previous three years' federal income taxes.

2) an amount carried forward and available to reduce federal income taxes for the next seven years.

In order to be eligible for the ITC, the assets must be used in a manufacturing and processing operation, an ore processing operation or a farming operation.

To be more specific, let's look at the installation of a wood-fired boiler for a manufacturing facility, again with equipment costs of $1,000,000. Because different areas of the country have different ITC benefits, let's assume that the equipment is to be located in Bathurst, New Brunswick.

For this area, the ITC rate for 1988 is 40% (30% for 1989) of the installed cost of equipment and the refundable portion of tax credit would be 40% of the ITC. Please note that the refundable portion of the ITC must first be used to reduce the current year's federal income taxes.

TABLE 2

IMPACT OF ITC ON CAPITAL COSTS

Equipment Cost	$1,000,000
Refundable portion of ITC @ 40% of $400,000	160,000
Net Equipment Cost	$ 840,000
Portion of ITC carried forward and available to reduce federal income taxes for the next seven years	$ 240,000

All actual refunds of ITC or amounts applied to reduce federal income taxes payable will reduce the balance available on which to claim CCA for the following year. Therefore, for the above project the undepreciated capital cost at the end of year 1 would be:

Original Cost	$1,000,000
CCA (assuming maximum claimed)	(250,000)
ITC refund (assuming nil federal taxes)	(160,000)
Balance carried forward to year 2	$ 590,000

The net effect of the refundable portion of the ITC is the same as a grant since it represents taxes already paid or to be paid from current year's operations. The effect of the investment tax credit in the following years is to shorten the period of write-off for the assets. Note that this is a tax credit and that it is obtained by filing the tax return.

If the project is eligible for ITC and Class 34 then the simple payout period would be further reduced.

Again, it is important to remember that the ITC is mainly a tax benefit available to manufacturing and processing industries. 40% of the credit available is received whether the corporation is taxable or not. The balance must be used to reduce federal income taxes otherwise payable and so <u>if you're not taxable there is no further benefit</u>. If you are taxable, the benefit comes from the difference in present worth between $1 of tax saved and $1 of income saved multiplied by the tax rate.

The production of steam or electricity for sale is not classed as "manufacturing or processing" for the purposes of the income tax act and so these plants are not eligible for investment tax credits. However, a steam or power plant installed by a manufacturing or processing facility for its own use is eligible.

With careful planning and organization, it is possible within a leasing arrangement to transfer some of these tax benefits between a lessee and lessor providing the lessee is in the business of manufacturing and processing, uses the assets leased in conjunction with that activity and the lessor is in the business of leasing.

What this means is that the user (lessee) can lease the equipment for "off balance sheet" purposes and could negotiate lease terms which would take into account the tax benefits which have been retained by the lessor.

To summarize, let's assume that a new wood-fired boiler was being considered for three applications:

1) a hospital
2) a university
3) a manufacturer

The basic tax considerations would be as shown in Table 3 for capital assets and Table 4 for operating costs.

Remember that the only advantage of the Class 34 (fast write-off) is that the Company's income taxes are reduced in the early years. Over the life of the facility, the amount of depreciation or capital cost allowance will be the same. The benefit then is the difference in the present worth value of the tax savings over the life of the project. Also remember that if the company is not profitable or not profitable enough to use the full CCA in the early years, then the value of the "fast" write-off is diminished.

TABLE 3

COMPARITIVE TAX FEATURES

FOR CAPITAL ASSETS

	Hospital	University	Manufacturer
Pay Provincial Sales (PST) Taxes	Yes[1]	Yes[1]	Yes[1]
Pay Federal Sales (PST) Taxes	No[2]	No[3]	No[4]
Receive Investment Tax Credit Refundable Portion)[5]	No	No	Yes[6]

NOTES:

1 - parts of boiler used directly in combustion are exempt from N.B. PST
2 - Hospitals are exempt from PST on all equipment purchases
3 - wood-fired boilers are exempt from PST
4 - all equipment directly related to production is exempt from PST
5 - This credit will vary depending upon the tax region in which the plant is to be built.
6 - Generally available to small businesses.

TABLE 4

COMPARITIVE TAX FEATURES

FOR CAPITAL ASSETS

	Hospital	University	Manufacturer
Basic Annual Costs	Base	Base	Base
Provincial Taxes On Supplies, Etc.	Yes	Yes	Yes
Federal Taxes On Supplies, Etc.	Yes	Yes	No
Capital Cost Allowance	No	No	Yes
Investment Tax Credit	No	No	Yes
Income Taxable	No	No	Yes

"Off balance sheet" financing usually involves a lease or similar arrangement whereby the ownership of the assets (equipment) in question rests with the lessor until certain conditions are fulfilled. With this arrangement, the lessee (user) enjoys the benefits of the new equipment over a specified period while the lessor finds the capital to make the installation and accepts some of the risk.

The detailed structure of the deal will vary for each leasing company and for each project. Also, the form of lease may be of the "capital lease" or "operating lease" variety.

Where the agreement is "capital lease", the lessee (user) becomes the effective owner of the equipment upon signing the lease and the financing becomes similar to a mortgage loan which is paid off over a specified period with the equipment being pledged as collateral. In this case the lessee treats the assets as his own for accounting and tax purposes. Under a "operating lease" lease arrangement, the lessor retains ownership of the equipment. The lessor (or owner) is able to include these assets on his books of account, to depreciate them in accordance with the lessor's normal accounting practices and to take advantage of any special tax treatment which may be available.

The use of capital lease financing by private companies has increased in recent years. In essence, this arrangement is very similar to leasing an automobile. The user (owner) strikes a price with a supplier and then a third party

(the lessor) comes in and leases the equipment to the user (owner). The lessor, looks at the user's ability to pay, a buy-out price at the end of the lease is established, and a monthly payment is agreed upon. In establishing the monthly payment, the lessor has to consider his cost of money, business risk, and the return on investment for his shareholders.

The cost of the financing over the term of the lease will be greater than if the user had borrowed the money itself. However, the user has not had to increase its long-term debt and would be entitled to any tax benefits associated with ownership. The return on shareholders' equity could be greater with this arrangement because the company's capital funds are available for other opportunities.

Another approach to financing has been used for energy conservation projects and is sometimes referred to as a "shared savings" concept. Here the developer designs, installs and starts-up the equipment for an agreed upon lump sum price and takes his payment from the savings generated by the project. This is done by defining each element in the project along with its cost and associated savings and then agreeing with the user to proceed with those which show a simple payback of less than 4 years. The user then pays to the developer <u>the lesser of</u> project costs plus interest on the outstanding balance, or five years worth of monthly savings in energy costs. After five years, the user makes no further payments and would become the owner of the equipment.

When energy costs were high, this was an attractive way for institutions and industries to finance energy conservation projects. The user had no debt obligations (off-balance-sheet financing) saved his capital for other uses, and paid for the equipment with energy savings.

On more recent and larger power plants burning wood fuel, it has been common for owners and users to contract for these on a design-build firm price basis and occasionally the contractor may also start-up the plant and operate it for a period of time before turning it over to the owner. Deferred payment terms may also be part of this arrangement.

Having reviewed some of the main considerations for financing, let me give you a brief outline of the development strategy which we adopted for wood-fired plants a few years ago.

In 1984, Northeast Energy Services Ltd., a New Brunswick Company, saw the need to encourage the use of wood wastes for fuel in heating plants. We noted a number of barriers to greater utilization e.g.:

- uncertainty about burning wood fuel (versus oil which was easier to handle)
- wood fuel not readily available (no formal distribution network)
- equipment costs were high compared with oil fuel
- capital funds were scarce

Northeast responded to this need by offering a contractual package which did the following:

(a) completed a feasibility study

(b) designed the plant

(c) constructed the plant at a firm price

(d) supervised the start-up

(e) trained the operating and maintenance staff

(f) financed all of the above by means of a lease/contract

(g) provided ongoing technical assistance as required

(h) provided processed wood fuel for the project on an "as required" basis for an agreed upon number of years

This arrangement made it much easier for users to acquire the wood burning equipment, to have access to technical support, to deal with firm construction costs, and to save capital funds.

In recent years, the Conservation and Renewable Energy Demonstration Agreement, a joint Federal-Provincial program, provided assistance toward the capital costs of wood burning plants and toward monitoring of performance for a period after start-up. The steam plants which we developed at the University of New Brunswick in Fredericton (1984), the Hotel Dieu Hospital in Chatham (1985), and the Charlotte County Hospital in St. Stephen (1985) were all supported by this program.

The term of this agreement expired on March 31, 1987 and at the present time no special assistance is available for such plants in New Brunswick. I believe that the Forest Industries Renewable Energy program also expired at the same time.

I understand that Energy, Mines and Resources is working on a new initiative for biomass as was mentioned in yesterday's sessions.

Generally speaking, neither the programs of the Atlantic Canada Opportunities Agency nor Department of Regional Industrial Expansion assist wood burning installations except when they are part of a manufacturing or processing operation or perhaps a hotel or tourism project. It appears that the collecting and processing of wood fuel as an industry on its own, could be eligible.

In summary, there are a multitude of ways to finance a project today ranging from simple debt or mortgage financing to the more sophisticated "capital lease" and "operating lease" arrangements. Each approach has its positive and negative aspects and deciding what's best for each particular application requires a sound knowledge of both the accounting and legal implications. In the final analysis, each customer must choose the option which best meets his functional and financial objectives.

DESIGN AND OPERATION OF A 7.2 MW WOOD WASTE CO-GENERATION PLANT - A CASE HISTORY

Peter Golobic - Ontario Ministry of Energy
Paul Shervill - Ontario Ministry of Energy
William P. Ivey - Chapleau Co-Generation Limited

Introduction

Chapleau Co-Generation Plant is a privately owned state of the art, 7.2 megawatt wood fired thermal electric generating facility. By safely and cleanly disposing of nearly 120,000 tons per year of sawmill waste produced by the three Chapleau sawmills, this plant is able to supply all the electrical energy requirements of the town of Chapleau, and most of the surrounding area. Steam for mill heating and lumber drying is also supplied to Chapleau Forest Products Limited.

History of Project

The initiative for this project came from the Ontario Ministry of Energy, which commissioned a feasibility study for a waste wood fired district heating plant. This report was circulated to prospective developers with the understanding that financial assistance would be available from the Ontario Ministry of Energy and the Department of Energy, Mines and Resources.

Foster Wheeler Limited, a major boiler manufacturer with its head office and manufacturing plant located in St. Catharines, Ontario, in April 1985 committed to build, own and operate this project in partnership with Mr. John Sereny, a Principal of one of the Chapleau sawmills, after demonstrating

the economic viability of the concept, and obtaining grant agreements from the federal and provincial governments. During the development of the plant design, it became apparent that the district heating scheme was impractical and this aspect of the project was dropped, but in turn provision was made for low pressure steam supply to the adjoining sawmill, Chapleau Forest Products Limited.

The project comprises a 70,000 pound per hour steam generator burning sawmill waste and a 7,165 kilowatt electrical generator driven by a condensing turbine, with an extraction port capable of delivering 25,000 pounds per hour of low pressure steam. It was designed to receive 65% of the plant requirements as "hog fuel" delivered by conveyor belt directly to the 20,000 cubic foot day bin during two shifts of sawmill operation. The balance of plant fuel requirements is delivered by truck, screened and delivered to the day bin via an inclined flight chain conveyor.

Ground breaking for the project was in September 1985. Foundations were poured and construction of the building continued during the fall and winter of 1985-1986. Major equipment began to arrive on site in April 1986. During this period, it became evident that the significant change in operating parameters would require substantial redesign of the fuel handling system and a corresponding major increase in capital cost.

The sawmills supplying waste wood fuel had moved to a single shift operation and indicated that they were unlikely to return to two-shift operation in the foreseeable future. This meant that the same daily volumes of wood waste would have to be handled in half the time. Secondly, a detailed study of the wood waste supply indicated that all available forms of waste would be needed to meet the plant's fuel requirements. This meant using low density planer shavings, which increased fuel handling equipment throughput requirements, as well as using solid wood (pieces of logs) which would require the installation of a hammer mill or "hog".

These changes necessitated a complete redesign of the fuel handling system and a corresponding increase in capital cost. At the same time, a review of water treatment requirements indicated that the high organic content of the Chapleau River water would create problems. The subsequent redesign of the water treatment plant also added to the cost increase. A complete review of project costs in April 1986 indicated a total capital cost of $14,000,000, an increase which required a review of the economic viability of the project and a subsequent increase in government funding.

Construction continued during the summer months, and commissioning activities commenced September 23, 1986, one year to the day after the original sod-turning ceremony. Commissioning activities and performance testing brought to

light several equipment and design problems which required some modifications to correct. Essentially, these revisions consisted of:

1) Replacing the organic traps in the water treatment drains with carbon filters to improve organic removal;
2) Removal of superheater surface and addition of an attemperator to control high superheated steam temperatures;
3) Addition of ash re-injection equipment to improve combustion and reduce carryover of unburned carbon.

The net result of these modifications was to increase total erected plant cost to $15,000,000.

Construction was completed January 29, and commercial operation of the plant February 1, 1987.

Technical Description

Major Equipment

Steam Generator

The 13.9 megawatt steam generator manufactured by Foster Wheeler Limited together with its auxiliary equipment occupies the northern half of the plant. The steam generator is about sixty feet high and has seven working levels. Fifteen tons of wood waste are burned in the furnace every hour to produce 70,000 pounds per hour of superheated steam at 900 psi. pressure and 8750 degrees F temperatures.

The wood is burned on a sloping, vibrating, water cooled "Hydrograte" supplied by Detroit Stoker Limited. Combustion air is supplied by two large fans inside the boiler house, and a larger induced draft fan which sits outside the building adjacent to the scrubber. Incoming air is preheated to improve overall efficiency and to dry the green or wet fuel on the grate.

Stack emissions are controlled well below required environmental standards by a mechanical cyclone type dust collector, and finally by a wet scrubber in the base of the stack.

Wood Handling System

The storage, preparation and burning of the forty thousand cubic feet of wood waste required daily, requires a reliable and highly automated system. Wood waste from Chapleau Forest Products Limited is delivered directly to the system by belt conveyor. Wood waste from the other two sawmills is hauled by the plant's own fleet of trucks to the short term storage pile at the east side of the plant. A live bottom yard stoker effectively moves this fuel from the storage pile to a chain reclaimer, disc screen and hammer mill and then to the large flight chain conveyor which fills the 20,000 cubic foot day bin.

The bin contains sufficient fuel for approximately twelve hours of operation. Hydraulic rams operate the live or moving bottom of this bin, which effectively shovels fuel into a smaller metering bin inside the plant. As fuel is required to maintain combustion, large variable speed screws auger the fuel from the metering bin into the boiler feed chutes and thence onto the grate. This operation is controlled by logic circuits in the Computerized Rosemount System 3 Control System.

Spray Pond

The rather attractive sprays of water beside the plant are not for aesthetic purposes, but are required to lower the temperature of cooling water before returning it to the Chapleau River. River water is circulated through the Foster Wheeler condenser, to provide the cooling which condenses the steam exhausted from the turbine. The condensed steam is returned to the boiler for reuse.

Electrical Substation

At the south end of the plant is a 7.5 MVA transformer and associated switch gear. The generator produces electrical energy at 13.8 kv, which is transformed up to 25 kv for export on the Ontario Hydro grid.

Boiler Room Equipment

In addition to the Foster Wheeler steam generator, the boiler room houses the deaerator and two large boiler feed pumps on the main floor. The steam and boiler feed water sample station, as well as the metering bin, fuel feed chutes and most of the control valves associated with the boiler operation are located on the third or operating level of the boiler room.

Turbine

The turbine-generator set and associated lubrication system was supplied as a package by Shin Nippon Machinery Limited of Tokyo, Japan.

This turbine is capable of taking 70,000 pounds per hour of high pressure steam and producing in excess of 7 megawatts of mechanical energy. Additionally, up to 25,000 pounds per hour of steam may be extracted part way through the expansion cycle to provide low pressure steam at 15 psi. for heating sales.

Generator

The four pole synchronous generator is driven by the turbine through a speed reduction gear so that the turbine is spinning at 5020 rpm and the generator at 1800 rpm which results in an electrical frequency of 60 hertz (cycles). Up to 7,165 kilowatts of power is produced at 13.8 kilovolts.

Control Room

A single shift engineer in the control room is able to monitor and control almost every function in the plant through the Rosemount System 3 computerized control system. The operator monitors and controls the total plant operation via the command console. The shift engineers are second class Stationary Engineers, who possess a broad range of skills which are required to operate a state of the art plant like Chapleau Co-Generation.

Commissioning

Commissioning activities were divided into minor and major categories, major activities requiring more extensive preparation and co-ordination.

Minor commissioning activities included pre-commissioning inspections of equipment and/or systems for mechanical completeness and compliance with drawings and specifications; performance of hydrostatic pressure tests; calibration of instrumentation and check-out of control loops; temperature and vibration testing of bearings; and noise level checks. These activities were carried out as required during the period September 1, 1986 through January 31, 1987.

Major Commissioning Activities

Major commissioning activities were carried out according to the following schedule.

1. Refractory Drying and Caustic Boil-Out

The boiler was fired with a temporary propane burner for this purpose. Firing commenced September 24 and was completed September 27.

2. Steam Blowing

Steam blowing to clean out the boiler and high pressure steam piping was performed using rupture discs which were calibrated to burst at 900 psig pressure. Firing for steam blowing commenced on October 3, and continued until clean targets were obtained on October 9.

3. Turbine Run-Up

Initial test of auxiliary equipment and protective devices for the turbine-generator set commenced October 12, 1986. Electrical testing of high voltage system began October 15. The turbine was first rolled on October 21. Over speed trip was tested immediately, and correct operation observed. Subsequently, all protective trips were operationally tested and verified.

4. Initial Synchronization

The generator was synchronized and connected to Ontario Hydro grid on October 24. All generator protective relays were varified, including remote trip signal from Ontario Hydro.

5. Load Rejection Tests

Electrical testing of generator, including voltage and power regulation devices continued. Generator loading was progressively increased, and safe tripping of the unit at various power levels was confirmed. This activity continued during the rest of the month of October.

6. Full Load Testing of Steam Generator and Turbine Generator

Excessive steam temperatures prevented safe full load operation, and eventually required boiler modifications. Successful full load operation was demonstrated, and safe full load rejection proved on December 1986.

7. Plant "Black-Out"

Safe plant shutdown upon complete plant power failure was also demonstrated on December 16th. An automatic reclosure on the Ontario Hydro Feeder on January 5, 1987 proved the effectiveness of the protective equipment and operating procedures.

Production targets were established for the initial operation of the plant at 50% capacity factor for the month of February, and 65% for March. Actual production for these months was 40% in February and 68% in March.

All data to date indicate that the plant is able to meet all environmental operating requirements specified in the relevant environmental certificates of approval. Particulate emissions testing was completed on April 30, 1987, in accordance with the original schedule. The actual results of the tests indicated that emissions level was only 27 micro grams/m^3 or 27% of the standard permissible (100 micro grams/m^3).

Plant Performance

Since the commercial start up of the cogeneration plant in February, 1987, the plant has performed to its expectations in the areas of availability, capacity factor and electricity production.

Plant availability exceeded 90%; the capacity factor averaged 74.3%. Electricity production from February 1, 1987 to November 30, 1987 was 34.3 million kwh and 8,517 tonnes of low pressure steam were delivered to the sawmill for timber drying.

Operational Experiences

1. Wood Handling

Waste wood fuel handling and processing is probably the most problematic area of the plant operation. Being a low grade fuel, relatively large volumes of fuel must be fired. Fuel heating value averages 4000 btu/lb, which is less than one quarter the heating value of no. 2 fuel oil for example.

Handling and processing problems are caused by the following factors:

a) Size Variation - feedstock varies from sawdust fines, through planer shavings and bark, to round waste which intermittantly includes logs up to 5 or 6 inches in diameter, and up to 8 feet long.

b) Foreign Material - tramp metal from the sawmills, and rocks up to ten or twelve inches in diameter occasionally come through the sawmill waste systems, causing damage to the disc screen, hammer mill and screw conveyors.

c) Moisture Content - year round average moisture content of the fuel is 50%, but climatic conditions have caused moisture content to be as high as 66%. Combustion problems necessitating boiler load reductions occur when fuel moisture content exceeds 55%.

d) Freezing - wet fuel is susceptible to freezing, especially when outside temperatures are around the freezing point. Fuel will freeze to metal surfaces throughout the whole wood handling system causing a variety of mechanical problems and stoppage.

2. Storage

It is necessary to stockpile fuel in a large outdoor pile to permit plant operation during sawmill shutdowns. We have found that fuel quality deteriorates with length of storage time due to loss of volatiles (e.g. turpentine) from rain and snow falling on the stockpile. Burning such stockpiled fuel can occasionally cause combustion problems and consequent loss of capacity.

3. Boiler

Wood is burned on a sloping, vibrating, water cooled "hydro-grate". This has proved to be most effective, and permits the operators to adapt to changes in fuel quality and consistency by changing the grate jog cycle, maintaining an even bed of fuel on the grate, and a steady fire.

Early combustion problems caused by variations in fuel quality (particle size and moisture content) were moderated to a significant extent by retro-fitting an ash re-injection system that blows fly ash from the boiler tube bank, and from air heater and dust collector hoppers back into the furnace above the grate. This yielded an improvement in efficiency and more stable combustion.

4. Turbine-Generator

The turbine, turbine controls, generator, and lubrication system were supplied as a package by Shin-Nippon Machinery of Tokyo. This is a simple rugged unit using very standard technology, and no operating problems have been experienced.

5. Cooling System

Raw water from the Chapleau River is circulated from a pump house on the river bank to provide cooling water for the condenser, the generator air cooler and the lubricating oil. The plant operates under an environmental certificate of approval that limits the temperature difference between cooling water inlet and outlet to a maximum of 8.3 C. Maximum cooling water outlet temperature must never exceed a maximum of 30 C. During summer months it is necessary to lower cooling water effluent temperature by the use of a spray pond which provides evaporative cooling before the water is returned to the river. Operating experience to date indicates that the environmental limitations can be met without difficulty.

Because the plant is located near a walleye spawning area which is important to the ecology of the river, Chapleau Co-Generation has funded a seven-year fishery study which is being performed by a private environmental research agency in consultation with the Ontario Ministry of Natural Resources. Results to date indicate no adverse effects on the fish population due to thermal discharge from the plant.

6. Water Treatment

An average of 20 gpm of raw water is required to provide boiler water make-up. This is presently treated by two parallel water treatment trains consisting of a multi-media sand/anthracite filter followed by an activated carbon filter for organic removal and a mixed bed anion/cation demineralizer. High organic content subject to considerable seasonal fluctuation in the river water has been a problem in that some organic fouling of the mixed bed resin has been experienced. The company is presently studying the alternatives of a clarifier and in-line clarification for pre-treatment of the raw water for organic removal.

7. Electrical Switchgear

An unusual problem has been experienced with blown high voltage fuses on the generator metering and protection potential transformer primaries. Ferroresonance is the suspected cause of the problem, but so far the standard "fix" of adding damping resistors to the potential transformer secondaries has failed to resolve the problem completely. This situation is still under investigation.

Innovative Features

Commercial Arrangements

Chapleau Co-Generation Limited is the first wood-fired cogeneration facility in Canada operating as an independent business venture. Revenue is derived solely from electricity sales to Ontario Hydro, and steam sales for mill heating and lumber drying. Wood waste is supplied by three area sawmills at a nominal cost. Collection, transporting and preparation (pulverizing) is carried out by Chapleau Co-Generation.

Given the relatively low avoided cost of electrical energy in the province of Ontario, and the consequent low energy buy-back rate, the economics of such an enterprise are marginal at present.

Commercial viability is achieved by streamlining all aspects of the operation as much as possible. All office functions are computerized and automated to the fullest degree. The plant itself is automated to the highest degree consistent with an acceptable capital cost. The entire process, including fuel preparation is controlled by a Rosemount System 3 control system, which permits the plant to operate with only two engineers on shift.

The plant's total staffing of 16 consists of: a manager, a chief engineer, 4 stationary engineers, 4 shift engineers, 2 maintenance men and 4 fuel handlers. The operating crews work on rotating shifts.

Zero Waste-Water Discharge

Capital cost was reduced, and many environmental problems were obviated by completely eliminating waste water discharge from the plant (excepting the toilets which drain into an orginary residential type septic system). All plant wastes, including water treatment wastes, blowdowns, floor drains etc. are evaporated in the wet scrubber.

The scrubber is capable of evaporating 18 to 21 gallons per minute at full load, depending on fuel moisture content. Waste water production is cyclic and intermittently exceeds the evaporation capacity of the scrubber. A large (50,000 gallon) storage tank was available locally as surplus, and was incorporated into the waste water system as a holding tank to accommodate surges in waste water production.

The system has proven to be effective, so the only residue from the operation is the wet ash which is presently hauled to landfill. Potential commercial uses for this material are under investigation, as the ultimate goal is to eliminate all waste disposal and to produce only saleable commodities.

Conclusion

Chapleau Co-Generation Ltd. plant has demonstrated the viability of utilizing the wood waste that would normally be land filled, for generation of useful electrical energy and low pressure steam.

Cooperative efforts of private industry and provincial and federal governments enabled the construction of the facility, that was the first of its kind in Canada.

The concept is now being replicated for additional wood waste burning co-generation facilities. A 9 megawatt and a 10.8 megawatt plant are scheduled for operation in 1989, and two other sites are undergoing feasibility studies. There is considerable future potential for these projects, since in addition to providing useful energy, they also contribute to a cleaner and safer environment.

Cogeneration projects, such as Chapleau, are sensitive to the utility's buy back rates and low fuel prices. Recent softening of oil and natural gas pricing added a further impact on the cost/economics of the projects.

In Canada, where the utility rates are reasonably low, the cogeneration plants still require some form of incentives to make them commercially viable. However, in parts of the U.S., where utility rates are higher, such plants would be in a more favourable position to achieve commercial viability, without government incentives.

SESSION "C"

Moderator: D.B. Curtis, Department of Natural Resources and Energy

1. RESEARCH AND DEVELOPMENT IN WOOD ENERGY HARVESTING AND HANDLING
   Dr. W.B. Stuart, Virginia Polytechnic Institute

2. EMISSION TEST RESULTS
   K.T. Fraser, Research and Productivity Council

3. SMALL/MEDIUM FUELWOOD CHIPPING
   Michael P. Folkema, Forest Engineering Research Institute of Canada

4. FUEL HANDLING SYSTEMS FOR WOOD-HEATING PLANTS
   J.F. Piercy, ADI Ltd.

RESEARCH AND DEVELOPMENT IN WOOD ENERGY HARVESTING AND HANDLING

Dr. W.B. Stuart

Virginia Polytechnic Institute

Introduction

I will surprise no one by saying that the glory days in wood energy research and development are over. The recent drop in oil prices, which precipitated the drop in coal prices, has led to a drop in wood usage. The relaxation of tensions in the Persian Gulf is giving indications that this moderation of prices may be long-term. Conservation is showing returns for both the private homeowner and industry. The cost of energy has returned to a tolerable level and led to a certain degree of complacency among consumers. Adventurous research in wood energy utilization is only going on in those countries such as Denmark with high oil taxes which artifically sustain the value of alternate energy sources.

This rather gloomy introduction should not be interpreted to mean that research and development in energy issues have ceased. Wood fuels have demonstrated their profitability in a wide variety of applications. The investment and effort which went into converting to wood as a fuel over the last 10 years is in place and bearing fruit. The confidence that we once had in unlimited supply of relatively cheap energy has been shaken. Most consumers, especially industrial consumers, who remember the oil shock of the 1970's

do not want to reach a condition of such vulnerability again. Economic consciousness has caused many industries and households to sharpen their pencils when calculating energy costs. What was once considered uncontrollable has been shown to be at least partly under the control of the consumer. Furthermore, increasing environmental concerns, a sustaining interest in natural fuels, as well as a possibility of using energy as a means of breaking even on environmental clean-up activities are important. In forestry, these imply site preparation, tract clean-up, and waste disposal activities.

In other words, wood energy has become accepted again, and since it is accepted, interest in research and development has declined to a sustainable, from a previously considered emergency, level.

For the rest of my paper, I would like to discuss research and development activities as a function of material types. The material types I intend to use are of three different categories: standing material, logging residues, and manufacturing residues.

Standing material includes stems or stands that are considered sub-merchantable by current conventional product standards and material arising from precommercial thinnings. Logging residues include the residual stems after the commercial stems have been removed as well as the logging slash, or limbs, tops, and broken stems arising from the removal

of the marketable product. Manufacturing residues include three subcategories: bark; wet residues, such as sawdust, green chain trim, and round-up veneers; and dry residues, such as planer shavings, grading table trim, and re-manufacturing residues. This categorization may not parallel one that you or the Canadian industry uses; however, it identifies potential products by a variety of characteristics which are useful in projecting their potential use. These characteristics include dispersion, recovery costs, transportation costs, and availability.

Standing Material

As mentioned earlier, two types of material are commonly included in this category. In regions such as the southern United States, our timber stands include a large component of unmerchantable stems at the time a harvest is conducted. This may include hardwood in-growth in natural and planted pine stands; whips, which are small, mature pine trees common in natural stands; less commercial species; small, crooked, and unmerchantable stems in hardwood stands.

Various attempts have been made at pre- and postlogging this material. Prelogging involves going into the stand and removing the energy wood component prior to the final harvest, where postlogging is going back in to recover the stems after the merchantable material has been removed. Of the two, prelogging appears the most feasible. A common practice

in much of the region is the specialized system enters the stand prior to the final harvest. At present, this commonly consists of mid-size feller-bunchers, 100-horsepower-plus grapple skidders, and a whole-tree chipper. Unmerchantable material is felled with the feller-buncher, skidded to roadside, and whole-tree chipped. The remaining crop trees are then harvested separately or re-sold.

This process results in minimal breakage. Felling a cull tree in a stand of crop trees will likely be less damage to those crop trees than felling crop trees in a stand of residuals.

Doing one harvest several weeks to several months ahead of the final harvest can result in minimal site impacts. The nutrient flush is broken into two separate peaks, the resulting stand is generally cleaner, and the amount of damaged timber is minimized. An interesting sidelight of this is that the merchantable material in a prelogged stand, if re-sold, often commands a higher price than wood being sold without prelogging. There are two explanations for this. One is logging costs reduced by having a cleaner understory, and second, timber buyers are more likely to look the stand over closely when they don't have to wade through all of the undergrowth and cull stems.

There is no new technology emerging to compete with the existing system in these stand types. The feller-buncher and grapple skidder appear quite economical as a means of recovery. There are several trials going on of flail delimbers in both thinning and prelogging as a means of recovering a higher percentage of usable fiber from these harvests than was available previously.

As many of you know, hardwood fiber usage has increased in the southeastern region as the supply has decreased. Consequently, there's a great deal more interest in recovering pulpable fiber from these stands.

Precommercial, or early, thinnings are much more common in Europe and Australia than on the North American continent. These result in silvicultural systems which start out with much higher stocking densities at establishment and are coupled with a genuine commmitment for silvicultural thinnings as a management tool. In many instances, this material was previously just thinned to waste, cut, and left to lay in the forest. Energy wood offers an opportunity to utilize the material; keep the stand floor clean to reduce disease, insect, and fire risk; and return revenue from a previous cost-only operation.

One technique that seems to be enjoying some favor is sour felling, cutting the stems and allowing them to lay in the field for periods of months to field-dry. This reduces the

moisture content of the cut stem; returns the nutrients in the needles and the twigs to the soil in the immediate felling area; and disconnects the falling, chipping, and transportation operations.

A variety of small, special-purpose chippers on farm tractor frames have been developed in Sweden and Denmark to serve in this application as a means of capturing this wood as a farm fuel or to serve district heating plants. The system usually involves using the same machine for recovering, chipping the previously felled stems, and transporting the chips to roadside, where they are piled down in the forest and protected, to be recovered as needed during the heating season.

Logging Residues

Logging residues generally show up very well on slides prepared by wood energy advocates as a potential source of energy simply because of the volume made available in any timber-producing region. A problem that is often overlooked is the difficulty of re-entering the stand after the merchantable crop has been harvested. This has proven much more difficult to do economically than many of the advocates perceive. The large volumes of down and broken stems, delimbed tops, bent and broken trees, and stumps left behind in a typical hardwood or mature pine logging operation in North American provide a major barrier to exploitation. In those areas with the more benign

species, such as the spruces in northern Europe, the volumes per acre and the dispersal of those volumes make the problem equally as difficult.

Despite this, the level of utilization has increased in the last 10 years. Hardwood and pine utilization limits have dropped to where previously unmerchantable stems are now considered part of the normal industrial furnish. Many areas have shifted to stands which had some level of management, and there is an increased concern worldwide with the cost, potential damage, and environmental impacts of the site preparation work necessary to restore forest productivity.

These concerns may provide an opportunity for increased work in this area, particularly as a concern over the use of fire, herbicides, and the aesthetic impacts of conventional logging increase in the more developed countries. In the United States, this remains as the major source of cut-your-own firewood. Scandinavian countries have developed a variety of systems based upon the Bruks chippers or tract mobile harvesters which can recover slash, limbs, tops, and cull trees and produce a usable fuel component. Concentration and transportation remain a major barrier to wide-scale recovery of this material. It can be very useful for on-farm use, district heating plants, and use in small communities. However, industrial usage is much more difficult to sell because of the unpredictability of supply and price.

The Scandinavian harvesting systems have proven a little difficult to apply in much of the rest of the world. The debris is scattered over the site at relatively low densities across broad areas, requiring in-woods processors to travel between accumulations and back to the roadside. Trials in Britain and Sweden of recovering with forwarders and then chipping at roadside have shown some promise, but the success is still being evaluated. An interesting sidelight of the trials in Britain has been a recognition of the value of partially decayed needles and twigs as potting soil and soil amendments.

The residue left by harvesting natural stands of North American hardwoods still pose a considerable challenge. Several different attempts have been made at developing equipment that could handle this material without bolewood attached. This includes the Canadian RECUFOR, the Houghton topwood harvester, some of the work that has been done at FERIC and at Auburn with roll-splitters, and the work that we're doing with both the baler and the roll-crusher. This is a tremendous resource and is worthy of continued exploration. Particularly since fire as a means of site preparation is being called into increasing question.

Slash at roadside is much easier to recover. This is generated in our region by gate delimbers and elsewhere by stroke delimbers. The dilemma that is commonly discussed is do

we return this slash to the forest to restore those nutrients which have been removed; do we leave it at roadside and burn it; or allow it to rot as part of the stand regeneration, or do we attempt to find markets? The tendency in much of the southern region is to relax wood quality standards and allow more stems to come in with limbs and tops attached as long as they meet state highway regulations. This topwood is broken in the drum debarker and passes along with the bark to the fuel hogs. This procedure is excellent in thinning loblolly pine stands and in slash pine (P. elliotti) operations, both of which tend to be relatively lightly crowned species. A major concern in other species is the amount of material generated by this system often overwhelms the bark conveyors in the mill, and, as you are probably aware, any problem inside the mill gates is a terminal problem. The applicability of recovering and utilizing this material is also a function of both soil type and site fertility. If organic matter or any of the nutrients contained in the residues is limiting, then returning this material to the site is probably the better strategy.

Manufacturing Residues

Bark is the most prevalent and most traditional of the manufacturing residues. The availability and price of bark in many regions is being influenced by alternate markets, most especially for landscaping mulch. This market appears to be growing rapidly and affecting the amount, price, and type of

bark available for use as a fuel. Supplies in many regions are tied up. In Virginia, most recently, one pulpmill has committed to sell all of the bark generated by the drum debarker to a mulch operation, replacing the fuel value with purchased sawdust.

A major concern of medium-sized consumers of bark, such as sawmills, is the cost of clean-up. The ash content of bark is roughly 10 times higher than that of other manufacturing residues and, consequently, imposes additional environmental problems.

Wet residues, those resulting from green manufacturing processes, include slabs, chips, green sawdust, and round-up chips. The availability of these is being influenced by changes in mill technology. Slabs which were once a major source of home fuel are increasingly being chipped for pulp furnish. Chips themselves have become a major source of fiber, and throughout most of the world the volumes of green sawdust generated per thousand board-feet of lumber cut is decreasing as mill technology advances. In many of the southern pine sawmills at present, there is a genuine concern that inadequate supplies of green sawdust are produced from manufacturing lumber to dry-kiln that lumber. In other portions of the region, green sawdust is becoming a disposal problem, specifically in the Appalachian hardwood mills. Changes in pulp and paper philosophy are also influencing the utilization

of green sawdust. A few years ago, it was perfectly acceptable in most mills to sell mixed chips and sawdust as pulpmill furnish. More and more mills are now requiring sawmills to screen their chips, separating the sawdust out for consumption on site. Sawmill technology, while reducing the amount of green sawdust, in many of the pine mills is increasing the moisture content of that same sawdust. The use of water guides to cool high-production gang saws has resulted in half the volume of sawdust at twice the moisture content being produced.

Traditionally, this sawdust was mixed with bark and burned on a flat grate to generate steam. McConnell of Trussville, Alabama has developed a slope grate burner for direct combustion, which appears to be getting good results. It is anticipated that the immediate future will see an increased usage of higher technology in sawdust combustion and dry-kiln heating, as well as continued exploration of processes for recovering fiber from the sawdust furnish.

Dry Residues

Dry residues include those components such as planer shaving, trim blocks, and re-manufacturing sawdust. These fuels are the best for most purposes. They have a relativley low moisture content (in the 10-20 percent range); they have low contaminants, being primarily clean, woody fiber; and the most consistent particle size. There are several competing markets arising for these residues. Animal litter is becoming

more important, especially as agriculture becomes more concerned about handling animal wastes. These dry residues can often be used in board products, especially particle board, as a surface layer. Increased exploration of reconstituted products may find the dry sawdust being an acceptable particle size for a variety of processes. Throughout most of the world, the prices vary due to local conditions. In many locations, the alternate markets for sawdust bring prices three and four times the value of direct combustion as fuel.

The Future

The best view of the process in the future is yet undetermined. Work is still going ahead on woody fuels on a much more controlled and deliberate basis than happened in the past. Many old processes are being refined and new ones are in the lab or developmental stages. For those engaged in this area of research, there are four destabilizing forces to be followed, which may have major impacts on the utilization of woody fuels.

The first of these, of course, is fuel prices. We're all aware now how quickly fuel prices can change depending upon factors well beyond our control. While we may be comfortable, we can't afford to be careless.

A second major issue is atmospheric deposition and the potential implications for the continued usage of high-sulfur coal. As most of you are aware, there is still a great deal

more fight than light on the whole question of acid rain. However, the use of wood as a co-firing fuel or to replace high-sulfur coal may increase in our lifetimes.

The third is questions concerning the disposal of solid wastes. Throughout the eastern United States, the water quality and air quality agencies are very concerned about the disposition of woody materials. Many landfills won't take it. Water quality boards are demanding that the amount of runoff from sawdust and bark piles be controlled and that special precautions be taken in site preparation activities. As the cost of disposing of solid wastes increases, the potential of recovering at least a portion of that cost by conversion to energy increases in kind.

The fourth is the developing alternate markets for biomass. The interest and work in wood energy has created a product type which may have applications well beyond just fuel. I talked of the landscaping mulch market earlier; however, this is just one of several different alternate markets which may offer promise to the producer. Other uses include temporary roads, chemical feed stocks, and absorbents, to mention a few.

At a meeting at Virginia Tech last summer, we asked representatives from North America, Europe, and Australia to talk about the problems and challenges affecting those contractors producing energy wood. A common feeling was that

the markets for the material are there, although they fluctuate as a price of the market fuels. The market prices at present are barely adequate to keep these producers in business, which is leading to shoestring operations and a considerable possibility that many of the suppliers will go out of business.

Raising delivered prices is not a viable alternative. These prices have been negotiated as a function of alternate fuels, and a raise in prices will cause an increasing shift to those alternatives. As a result of this discussion, it appears that it may be time for those of us interested in wood energy to look around and address the potential of developing alternative markets for our product. These markets may be in the traditional forest products area such as pulp furnish or board products in consumer goods ranging from mulch to cat litter or in other areas such as soil amendments, pollution control, chemical feedstocks, or wherever the human mind may lead.

Fuel should be a major concern. However, the development of these alternative markets can stimulate additional research and development, generate additional revenues, and provide the alternate seasonal or economic markets necessary to support the producer and the product.

EMISSION TEST RESULTS

K.T. Fraser

Research and Productivity Council

Background

RPC has been involved for a number of years in the examination of residential and small commercial wood burning appliances of a variety of types. We have looked at simple wood stoves, gravity and stoker fed wood chip and sawdust burners as well as larger commercial boilers and furnaces of the chunk wood burning type. These investigations have delved not only into the mechanical workings and safety considerations of the units, but also into their thermal efficiencies and emissions characteristics. Most of this work was carried out in the laboratory under controlled conditions although on a number of occasions field trials were conducted as well.

Introduction

This paper presents the results of emissions testing that was carried out at RPC over a period of years. Three types of combustion systems have been selected for discussion here; a basic wood stove, a stoker fed boiler unit and a gravity fed boiler unit. Many fuel types were examined, including douglas fir 2 x 4's, maple chunk wood, hardwood and softwood chips, sawdust and peat logs. It should be noted that this work was generally aimed at defining the operating parameters of the equipment rather than developing a profile of emissions versus wood type. In this regard it will be observed

that a variety of woods in a number of forms and at varying moisture contents were combusted, rather than a single species in one form at a variety of moisture contents or in a variety of forms at a single moisture content.

Test Method

The unit under investigation was placed on the platform of a digitally indicating weigh scale in order to determine the rate of fuel consumption during the test (Figure 1). This technique is only applicable to systems burning chunk wood or those of the gravity fed type where the fuel hopper is an integral part of the unit. Appliances utilizing a screw feed device are calibrated prior to testing by running the fuel into a container of known volume and time taken to fill it.

During the burn the flue gas was monitored continuously for the concentrations of oxygen, carbon dioxide and carbon monoxide as well as for temperature. Sampling of particulates was carried out in a dilution tunnel which consisted of a conical, galvanized metal hood located over the flue pipe of the appliance, connected to a vertical length of ductwork which was in turn attached to a blower system. The flue gas was drawn through the tunnel, along with room temperature air, to produce mixing and cooling. Particulates were sampled in the dilution tunnel with an apparatus comprised of a vacuum pump, a sampling probe, a pair of filters, a cooling

section and appropriate regulators and gauges. The temperature, flow rate and relative humidity in the dilution tunnel, the filter temperature, sampling flow rate and a number of other parameters were also recorded during the test. All information was fed to a data logger which produced a hard copy of the test results while at the same time sending the information to a computer for later processing.

Results

Wood Stove

Figure 2 presents a plot of particulate emissions in g/kg of wet fuel consumed versus the moisture content of the fuel (wet basis). This work involved a standard wood stove in which two fuel types (douglas fir 2 x 4's* and maple chunk wood) were used. The stove was run at maximum burn (air dampers wide open) then at 70%, 40% and 15% of maximum when burning douglas fir and at maximum and 70% of maximum when burning maple.

Examination of this graph indicates two points of interest. Generally speaking, as moisture content rose so did the levels of emission. Also, it can be seen that the rate of combustion, governed by the amount of combustion air supplied, played an important role in the generation of particulates. As the supply of air decreased, the emissions increased.

In Figure 3 particulate emissions have been replaced by carbon monoxide (CO) emissions. The importance of adequate combustion air is clearly illustrated here. As combustion air was decreased CO emissions quickly rose. Again, at maximum burn and 70% maximum burn the higher moisture content maple produced greater levels of CO than did the douglas fir at similar burn rates.

Stoker-Fed Boiler

A stoker-fed boiler system was tested using a variety of fuels and the results were plotted as Figure 4. Both particulate and CO emissions are shown on the same pair of axes. CO in particular exhibits the trend of increasing levels with increasing moisture content. This relationship did not extend to particulates however.

Gravity-Fed Boiler

Figure 5 presents the test results of the third combustion system, a gravity-fed boiler unit. As previously, both particulate and CO emissions were plotted on the same axes. These tests differed from previous ones in that both chunk wood and wood in the residue form (chips and sawdust) were combusted. In addition, small peat logs were also burned for comparison. The maple chunk wood generated higher levels of particulates and CO than any of the other fuels, regardless of moisture content.

Looking at fuels other than maple, the tendency toward higher CO levels at higher moisture contents occurred once again. Particulates, on the other hand, reacted in just the reverse manner.

Summary

Figure 6 summarizes the particulate emissions results examined previously. It will immediately be observed that these emissions are higher when chunk wood is burned. The wood stove particulate emissions are greater than all others, except that representing 20% moisture content chunk maple burned in the gravity-fed boiler.

Figure 7 presents a similar summary of the CO emissions results. All levels generated by the wood stove burning chunk wood were higher than those generated by any other appliance.

Chunk wood in the gravity-fed boiler generated more CO than any other fuel burned in this unit. The chunk wood CO level found here was in the range of the best performance by the wood stove and essentially equal to the emissions generated by the stoker-fed boiler using the wettest fuels.

Conclusions

The moisture content of the fuel being burned had a significant impact on the levels of emissions generated; as the moisture content rose, generally speaking, so did the emissions.

All other parameters being equal, fuel in the particulate or residue form produced lower levels of emissions than fuel in the chunk form.

The design of the combustion unit was also of great importance in determining the emissions which were generated during its operation. A simple wood stove, particularly when operated in the air-starved manner which is common practice, cannot generally perform as well as a properly designed boiler or furnace.

Further work is certainly necessary to precisely define the relationships indicated in this discussion. The results presented only serve to give a general overview of the situation and point the way for further investigation.

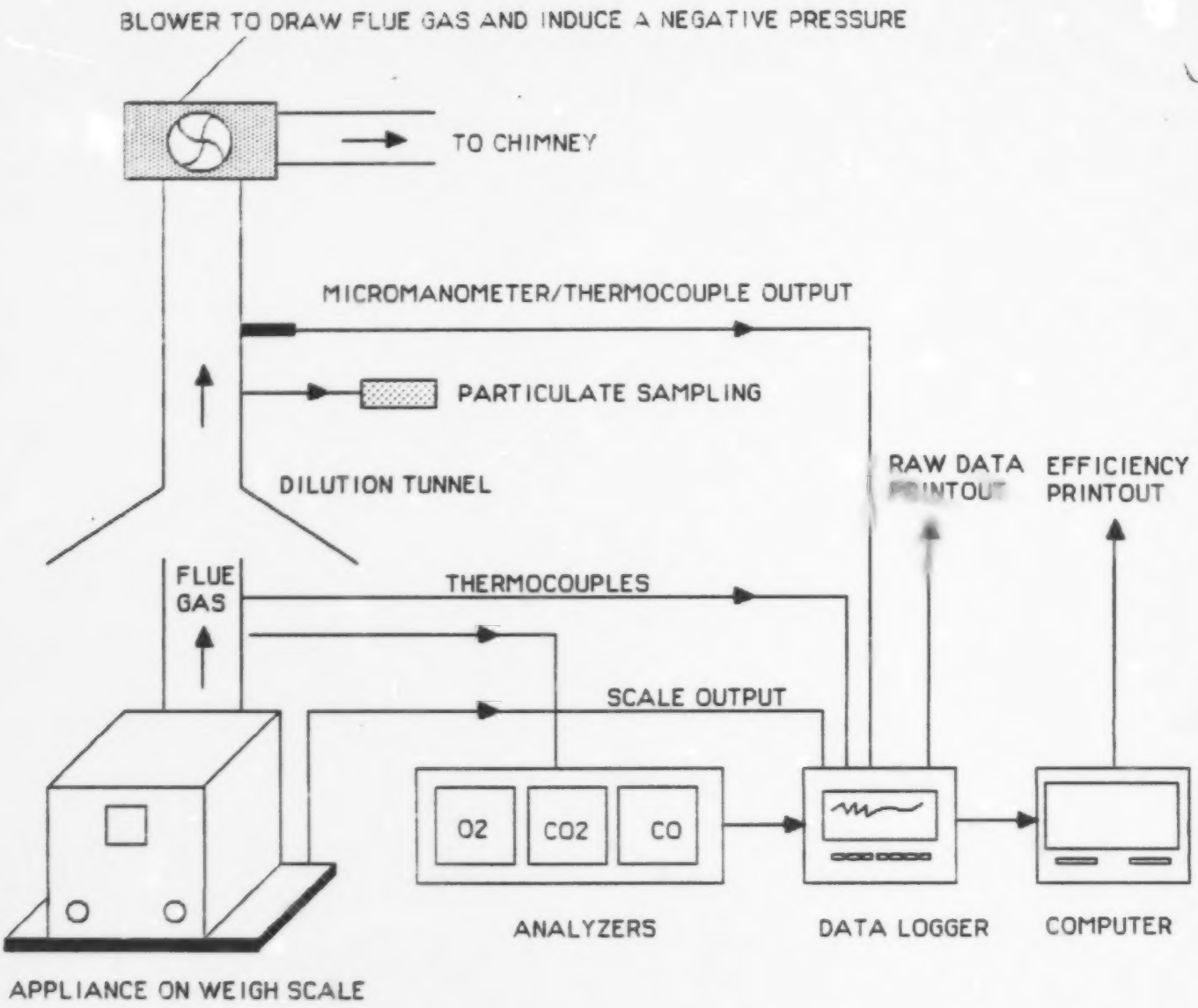


FIGURE 1
RPC COMBUSTION TEST FACILITY

FIGURE 2

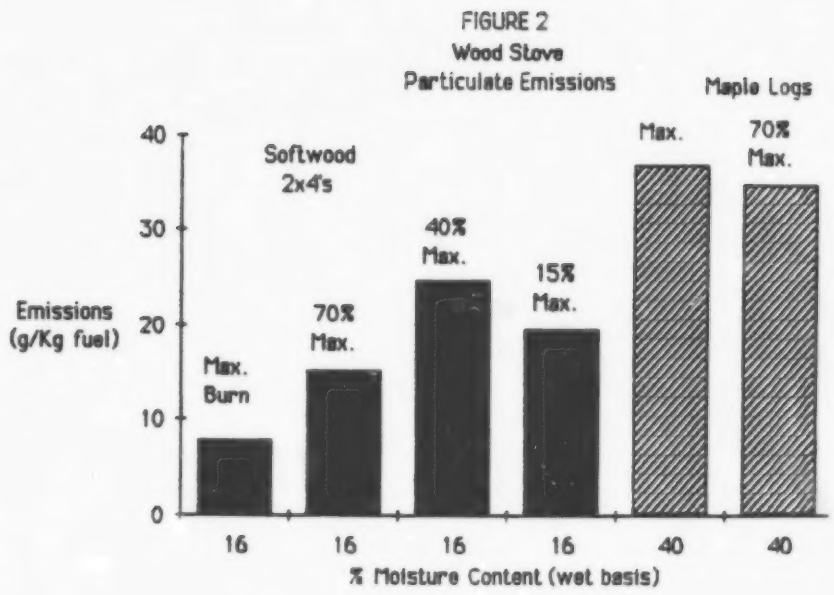

Wood Stove
Particulate Emissions
Softwood 2x4's
Maple Logs
Emissions (g/Kg fuel)
40
30
20
10
0
Max. Burn
70% Max.
40% Max.
15% Max.
Max.
70% Max.
16
16
16
16
40
40
% Moisture Content (wet basis)

FIGURE 3
Wood Stove
CO Emissions

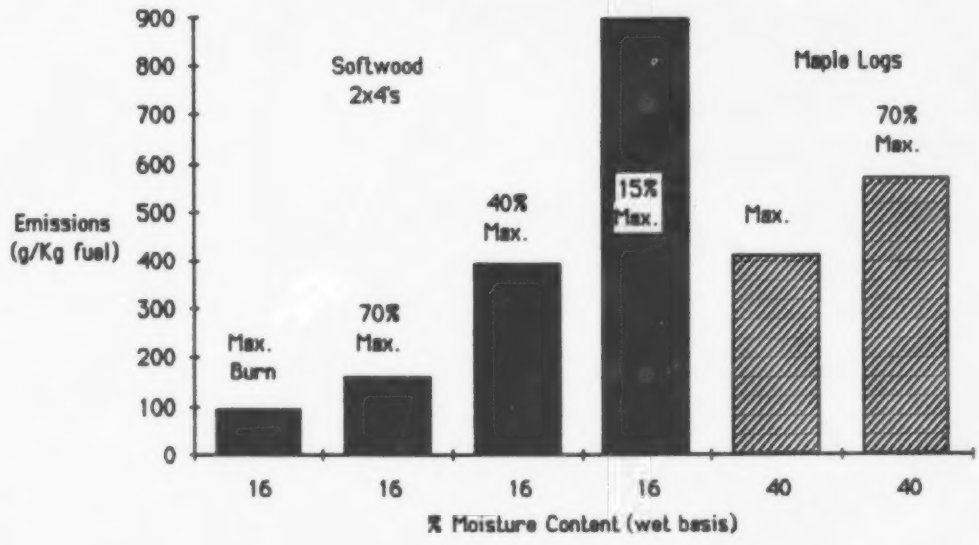


FIGURE 4

Stoker-Fed Boiler
Particulate and CO
Emissions

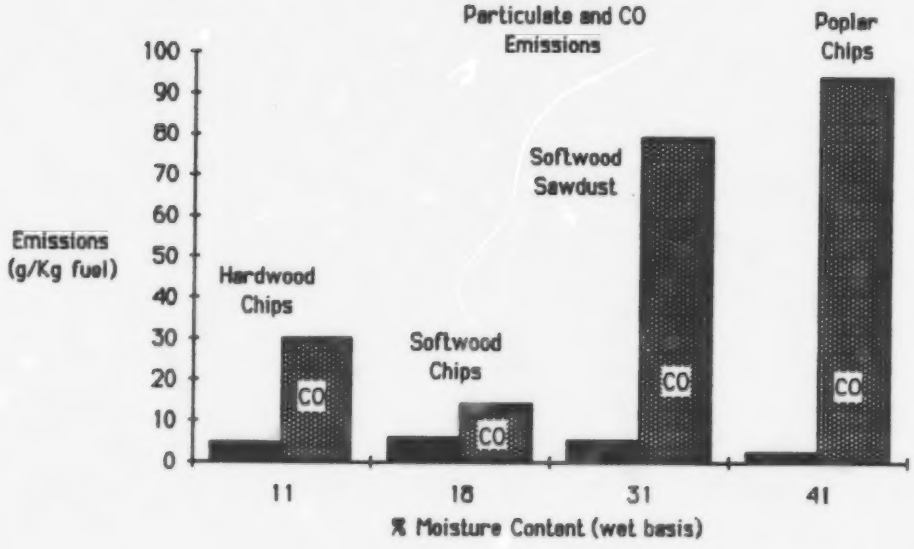


FIGURE 5

Gravity-Fed Boiler
Particulate and CO Emissions

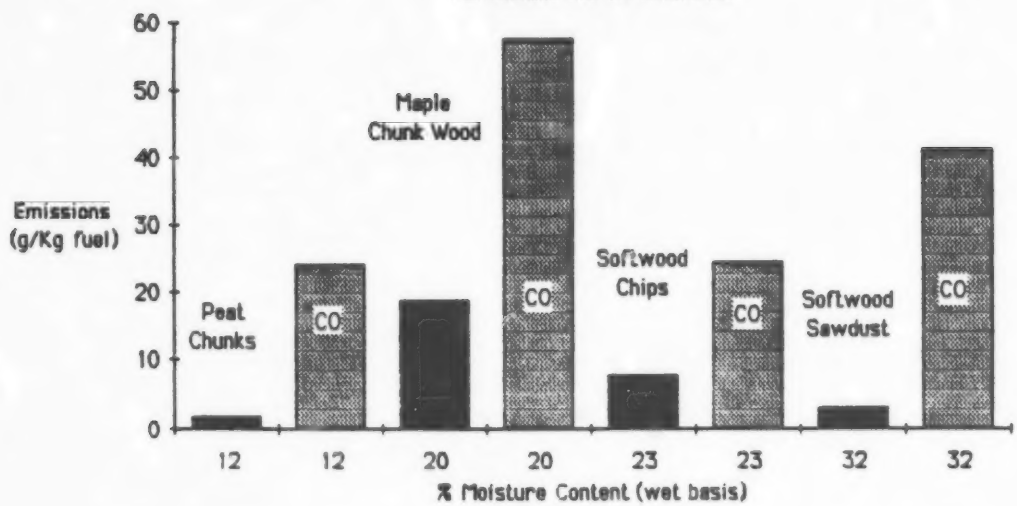


FIGURE 6

Particulate Emissions
Summary

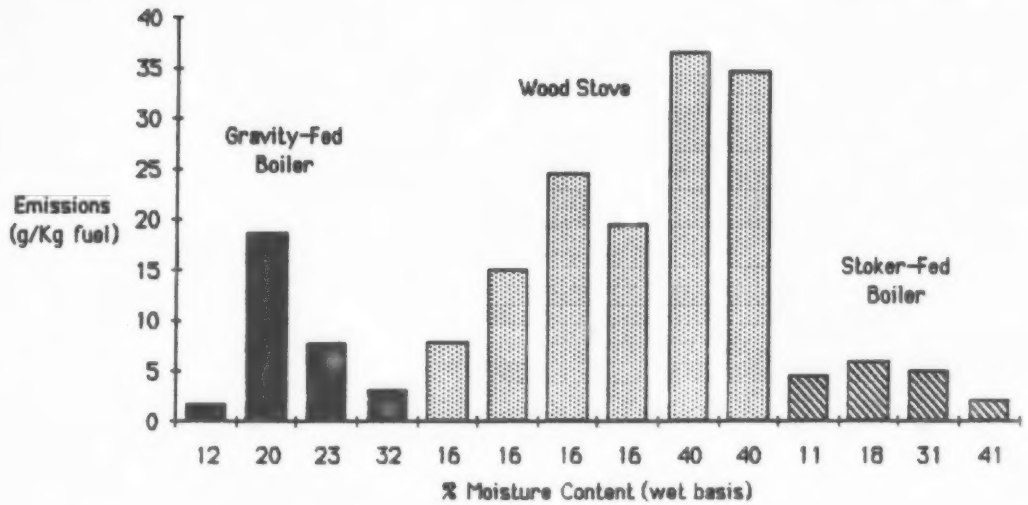
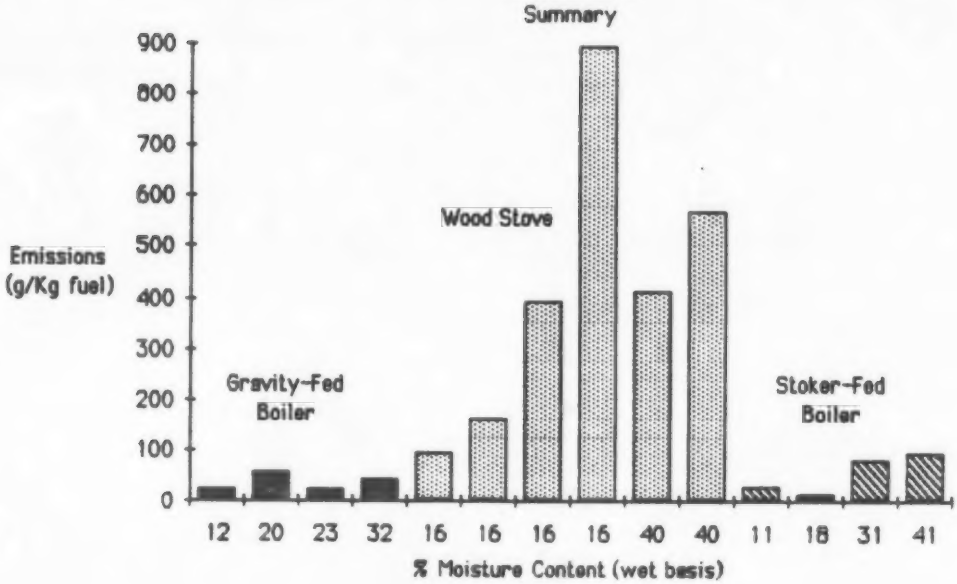


FIGURE 7
CO Emissions
Summary



SMALL-MEDIUM FUELWOOD CHIPPING

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Introduction

During the winter of 1988, FERIC personnel made a series of visits to small/medium-scale fuelwood chipping operations in Atlantic Canada and Maine. This was done under a contract financed by the Nova Scotia-Canada Memorandum of Understanding on Energy Conservation and Alternative Energy. The objective was to provide logging entrepreneurs with the information that they require to produce fuelwood chips efficiently and at the lowest possible cost. The information from the case studies has been analyzed and will soon be published as a FERIC handbook titled "Handbook for Small/Medium Fuelwood Chipping Operations".

Annual Production

The first step in determining the feasibility of a fuelwood chipping operation is to analyze the potential market. Obviously there must be one or more biomass burning facilities in the area. There may also be other markets for whole-tree chips; for example, some pulpmills (e.g. kraft pulpmills) can use barky whole-tree chips for their pulp furnish. Other potential uses for chips include animal bedding, sewage treatment, recreational trails, landscaping, etc. These potential markets should be investigated.

Recently it has become possible to produce high-quality pulpwood chips (e.g., 1 or 2% bark content) from whole trees in the forest by using a chain flail unit in front of the chipper to remove the limbs and bark. The flail units can be purchased separately (e.g. Manitowoc) or combined with the chipper in one machine (e.g. Peterson-Pacific, Foremost, MacMillan units). Their use may help contractors to increase their chipping volume, which should help to lower unit costs. It may also reduce the problem of seasonal fluctuations in demand for fuelwood chips. Some of the operators visited by FERIC had chip markets only during the cold season. The appeal of a larger market for chips is obvious. Large-scale chip producers report direct chipping costs of $5 to $7 per tonne. Small/Medium fuelwood chip producers usually have higher chipping costs mainly because of the smaller quantity produced per year.

Location

Fuelwood chips and hog fuel are more bulky and inconvenient to handle, transport, store, and burn than conventional energy sources such as oil, natural gas and electricity. Thus on a BTU basis, wood fuels will always be priced lower because of the inconvenience factor. Transportation costs of chips on a small/medium operation are typically 1/3 of the total price (e.g. haul costs of $9 to $10 per green tonne are typical for a 30 km haul). The current delivered price is typically $28 to $30 per green tonne.

The quality of the roads where hauling is to take place is important. In springtime it may be necessary to deliver chips when "half-load" restrictions are in effect. In such cases, consideration should be given to logging areas on higher ground and/or establishing a chip storage area near the biomass burner.

Choosing A Chipper

The whole-tree chipper is the most important piece of equipment on a chipping operation and should be chosen carefully.

(See Table 1. Whole-Tree Chippers-Roadside [1], [2])

It is wasteful of capital and working funds to have unused productive capability. Since a medium-size chipper that produces an estimated 150 green tonnes per day can cost as little as half of what a large chipper costs, this is a serious consideration. Plans should be firmly established to achieve full production as quickly as possible for whatever size chipper is selected. NOTE: The purchase of used chippers is common for the small/medium scale fuelwood chip producers visited by FERIC. The lower price means lower monthly payments and less pressure to reach the full production potential of the chipper.

Table 1. Whole-Tree Chippers - Roadside [1,2]

Chipper Size Class	Maximum Diameter Of Trees	Maximum Production (tonnes/day)	Average Production (tonnes/day)	Price New (C$)
Small	12"-14"	75-150	75	$100,000 - 150,000
Medium	18"	150-250	150	$150,000 - 200,000
Large	22"-25"	300-500	300	$300,000 - 400,000

1 Terrain chippers (e.g., Bruks) can chip material up to 12" or 14" (depending on the model). They cost $380,000 to $480,000 if purchased new, including the forwarder base unit (1988 prices). They are not included in Table 1.

2 Farm tractor PTO-type chippers are not included since they are not recommended for commercial harvesting.

Some stand factors that should be considered are:

Tree Diameter - Although there are many variables that affect the power required by the chipper it is generally accepted that the larger the diameter of the trees the greater the horsepower that is required for chipping. A general rule of thumb for soft or medium-dense hardwoods (e.g. poplar, birch) using disc chippers is 250 hp for 12" trees; 300 hp for 15" trees; 350 hp for 18" trees.

Tree Species - The "hardness" of some species will have a major effect on chipping production (e.g. a 12" sugar maple or iron wood requires much more chipping power than a 12" poplar).

Brush vs. Whole Trees - Various studies have shown that the cost per tonne of chipping brush/tops is much higher than for chipping whole trees. Also, chipping production is much higher when chipping large diameter trees than small trees. NOTE: Multiple tree feeding of small trees may offset this tendency.

Other factors which relate to chipper design are:

Roadside Vs. Terrain Chipping - Terrain chippers usually produce fuelwood chips at a higher cost than roadside chippers; however, there may be silvicultural, or other benefits that offset this higher cost. NOTE: an important advantage of the Bruks terrain chipper for small/medium biomass burners is that it produces uniform chips, free of long slivers that can plug auger-type infeed conveyors.

The Bruks chipper (and other brands of drum chippers) can also be purchased without the dumping bin mechanism. A Bruks chipper observed at Cornerbrook, Nfld. had no chip dumping bin and was mounted on a Timberjack 230 forwarder.

PTO-Powered Chippers - The maximum power that can be safely transferred through a PTO-shaft varies from 100-150 hp. Since it requires about 250 or 300 hp to chip 14" trees at a uniform rate, the PTO-type chipper is suitable only for small trees (6" to 9" diam) and should not be considered suitable for commercial fuelwood chipping. Many PTO-type chippers are handfed. They are best suited for use on farms and residential areas where small qualtities of chips are required, or where small-diameter trees must be disposed of.

Mobility - Where harvest blocks average 10 hectares or less a large roadside chipper (e.g. Morbark Model 22) may not make sense because its productive capacity is so great that it would have to be moved too often. It is more difficult and costly to move large machines than small ones. Short moves present less problems than long moves. The cost of preparing landings for the chipping operation should also be considered.

Infeed System - The knives on disc and drum chippers pull the tree(s) forward as it is being chipped. Thus feed rollers need not always be used. However, when feeding brush and tops, powered feed rollers are necessary on both

the top and sides. The lack of movable, powered feed rollers to feed and crush branches and brush is a major limitation on some lower-priced chippers. An inexpensive chipper is likely to have an infeed system that is not suitable for brush (unless the brush is first cut into segments).

Loader - Most chippers are equipped with a loader to feed trees. This is usually the best choice. However, if a logger already has a log loader that can be used to feed a small or medium-size chipper it may be financially attractive to use that loader with a chipper having no loader because it reduces the financial risk.

In some cases loaders have been installed on chippers with the hydraulic power for the loader coming from the chipper's engine. This "robs" power from the chipper which may adversely affect the chipping power and feed rate.

Long Slivers - are oversize chips, typically 6" to 12" (or more) in length. They are produced in both disc and drum chippers and are usually cut from the last part of a log as it flips up parallel to the knives. The knives bite into the piece sideways rather than on its end, thus producing long slivers. These long slivers are no problem for the large belt conveyors, used in large-scale facilities such as pulp mills and co-generation plants (these larger installations usually have screening systems and rechipping equipment for oversize chips; small/medium scale

installations do not, because of the extra cost). However, long slivers present major problems for small-diameter auger-type conveyors, the type commonly used for small/medium-size boilers. Usually the smaller the diameter of the auger, the greater the problem with long slivers.

In Scandinavia, small boiler installations are much more common than in Canada. Some Scandinavian disc chippers are available with a chip breaker on the disc behind each knife, which breaks up the long slivers into smaller pieces. Disadvantages of the chip breakers are that they have a tendency to get plugged with twigs and long slivers and that they require extra power from the engine. The best results are with bole wood. Some Scandinavian drum chippers (e.g. Bruks) are available with a screen mounted on the chip outfeed chute. Long slivers hit the screen, fall back and are rechipped by the revolving knives. To date, North American chippers have not been provided with these devices. In North America, there are relatively few small/medium whole-tree chip boilers in use. Many of them are in Atlantic Canada; they have been installed in the last few years. Since small diameter, auger-type conveyors have seldom been used in North America for conveying whole-tree chips there has been little awareness of the "long sliver" problem for small/medium installations.

Boiler Design - Some small/medium boiler installations are designed for a specific fuel with a very low dirt content. Excessive dirt in the chips (particularly in the mud season) can easily result in reduced operating efficiency of the boiler. Boilers having "moving grates" have less problems with dirt than others. If the boiler is "dirt sensitive" terrain chippers or forwarders with roadside chipping will usually provide cleaner chips than skidder operations with roadside chipping.

Felling Method

On most of the small/medium size operations visited by FERIC personnel, felling was done manually. On these operations, the volume harvested was usually too small to justify the use of a feller buncher. However, if the volume could be increased, feller bunchers would be considered.

Skidding /Forwarding

A variety of skidding/forwarding methods were in use on the operations visited by FERIC personnel. Experimentation with both skidding and forwarding had occured on some operations. The following methods were in use:

skidding with cable skidders;

using both skidders and forwarders;

chipping in the terrain with chips forwarded to roadside with a Bruks chipper; mainly full trees were chipped;

chipping with a Bruks in the terrain and at roadside. Tree sections/slash were brought to roadside by a forwarder equipped with an aluminum deck (a "brush carrier"). NOTE: This was also a land clearing operation;
forwarding small trees and tree sections with a standard forwarder.

Cable skidders are widely used on small/medium scale chipping operations. The main advantage of cable skidders is that they are versatile and can work in almost any type of terrain or stand conditions. For example, in soft ground, they can drop the load, drive on and then winch in again. This is not possible with grapple skidders. Disadvantages of cable skidders for chipping operations include the fact that trees are sometimes dragged through the mud. Mud, sand and stones can cause dulling of the chipping knives and result in excessive knife maintenance. This is particularly true when the mud freezes onto the logs before chipping can occur. Another disadvantage is that it takes a long time to place chokers on small diameter trees, especially if they are scattered residuals and cannot be bunched together.

Forwarders can be used to haul logs, tree sections or brush. Forwarders keep the wood clean of mud, which may be an important factor for chipper knives. However, brush/tops does not provide enough weight, and the resulting forwarding cost (on a per tonne basis) will be high.

The Bruks terrain chipper performs best on level, firm terrain with forwarding distances under 150 m. If working on slopes or in soft ground, stability problems can be expected since the loaded unit is relatively heavy and has a high centre of gravity. Production is considerably higher when chipping full trees as compared to chipping logging slash.

Chip Loading & Hauling

Loading chips into trucks or vans is usually a simple operation. For roadside chippers the chips are blown in through the open rear doors. On the Bruks terrain chipper the chips are dumped into a truck or van. It is not advisable to dump chips on the ground at the logging site and to load them later with a front-end loader or bucket loader since re-loading will add several dollars per tonne to the cost.

On small-scale chipping operations when using a single or tandem-axle truck it is common for the truck driver to operate the chipper. Chipping stops when the truck is filled. On medium and large-scale chipping operations there is a designated chipper operator. An old truck tractor or skidder equipped with a fifth wheel can be used to position empty vans beside the chipper.

During FERIC's visits, the type of truck used for hauling whole-tree chips varied according to the amount of chips delivered per day, the haul distance (1-way), the turning room available at the boiler or chip storage site, the design

and capacity of the storage bin and the funds available. The types of trucks and vans in use at the operations are outlined below. All were diesel-powered:

Single-axle truck - 6 to 8-tonne load - Usually the haul distance was less than 15 km. However, in one case study the haul distance was 50 km. NOTE: The load size of single-axle trucks is too small; tandem-axle trucks with a 12-13 tonne capacity are more economical to operate (but cost more to purchase).

Tandem-axle truck - 12 to 13-tonne load - Usually the haul distance was less than 15 km. NOTE: Large capacity dumping trucks (20 tonne load) are also available but were not observed during this study. The possibility of upsetting the truck while dumping is greater for trucks having long dump boxes. Ground firmness and wind velocity and direction are important considerations. A truck upset occured on one operation during high winds.

Pallet-type containers - Two operators had pallet-type containers that held up to 15 tonnes. Usually the truck driver hauled single containers for distances up to 30 km. The Nfld. operator hauled converted 20' cargo containers that held 11.5 tonnes. Usually single containers were hauled up to 15 km. For both operations it was possible to haul two containers if a pup trailer system was used. The Nfld. operator had a self-steering axle on the front of the pup trailer; the PEI operator, a rigid axle. The self-steering axle has the advantage of less sway on the road.

45' van - 30-32 tonne load - This operator hauled whole-tree pulp chips (higher value than fuelchips) over 200 km to a pulpmill. A large chip van such as this is required for long distances (smaller loads are uneconomical).

40' "chain-type" self-unloading van - 24 tonne load - A Nova Scotia operator hauled to several different boilers with a "chain-type" self-unloading van which held 24 green tonnes; one of the boilers was located over 100 km away. Self-unloading vans have moving floors that push the chips out the rear of the van. This system worked well. NOTE: Hydraulically-activated moving floors (e.g. Hallco-Glide Live Floor) that push the chips out the rear of the van are usually better than the older "chain-type" moving floors. A Hallco floor, when installed in a new 45' chip van, adds about 400 kg to the weight of the van and costs about $20,000. Unloading takes 8 to 10 minutes; partial loads can be dumped, if necessary, for small deliveries. Advantages of the Hallco over "chain-type" floors include lower weight (400 kg vs. 4000 kg) and thus increased payload (30 vs. 26 green tonnes for a 45' van), lower maintenance costs and reduced problems with unloading frozen loads of chips in winter.

Chip Measurement

Proper measurement ensures that the buyer obtains the correct amount and quality of chips. There are many variables that affect the amount or quality including moisture content, wood density, wood soundness, dirt content, species, chip size,

etc. For fuelwood the most important variable is usually moisture content. It is important not only because high moisture content means more water and less wood fibre but also because high moisture chips burn less efficiently and produce less heat.

On larger chip-burning installations (e.g., pulpmills) there is usually a weigh scale to weigh the chip truck going in loaded and going out empty. A sample of wood chips is taken from the load and is dried in an oven to determine moisture content. Payment is usually made on an oven-dry or bone-dry basis.

However, for small boiler installations it may not be economically feasible to install and operate a weigh scale and to sample for moisture content on each load, particularly if the loads are small. If there is a weigh scale nearby that can be used this should be utilized. On one operation the lack of access to a weigh scale was solved by weighing a number of sampling truckloads over a number of months. It was determined that an average load on the tandem axle dump truck was 12.8 tonnes. When a load was to be delivered, the boiler operator would check to see that truck was fully loaded and then would give the truck driver a signed receipt. Although this system worked well, it is less accurate and more open to abuse than the weigh scale method.

Chip Unloading

Chip unloading facilities should be fast, efficient and accessible. Factors that place constraints on unloading will tend to increase the final cost of the chips. Several of the installations visited by FERIC were not well designed for unloading.

At one installation the chip storage bin had large, heavy, nearly horizontal doors that were almost impossible for one person to open. There were no cross-augers to feed chips to the back. To fill the far side of the bin the truck driver had to get inside and use a shovel. Also, chip dumping could only be done between 9 a.m. and 4 p.m. The driver hired a second person for one or two hours per day to help open the bin doors and shovel the chips to the back of bin. Restrictions on dumping hours meant that a load produced one day might be delivered the next day with the driver taking the loaded truck home, which resulted in extra driving and higher costs. NOTE: All of the above problems were foreseeable and could have been prevented.

At another operation, a second potential market for fuelwood chips was available but no one tendered on it. The storage bin was so small it could not hold a complete load of chips from the tandem truck (12.8 green tonnes) even if the bin was empty. Also, maneuvering room even for a small truck was very limited.

On many of the boiler installations visited by FERIC there was not enough manoeuvering space to back in with a semi-trailer and 40' self-unloading van. These types of vans are cost-effective for hauling fuelwood chips especially for longer distances (over 50 km) which may be necessary when one chip producer supplies several customers. Chip dump facilities and driveways should be able to accomodate these longer vehicles.

Chip Storage

A chip storage facility is required when regular chip deliveries cannot be made because of poor weather, trail and road conditions. Most chip bins for small-to-medium size installations had a 3-5 day storage capacity, based on full boiler heat requirements. Spring break-up is usually the period when the most problems occur; the heat demand is high but regular chip deliveries cannot be made because of poor road conditions.

There are several possible solutions. One is to move the chipping operation to high ground so that logging (or chipping of stored trees) and hauling can continue. Another is to switch to another energy source (e.g., oil or electricity) if this is practical. A third alternative is to set up a storage area for chips near the boiler.

At one operation there was a large paved storage area adjacent to the boiler where the chips were loaded by a

front-end loader onto a conveyer for screening and to fill (3-day) storage bin. This worked well.

At another operation a 1 1/2 acre paved storage area (with a chain link fence and electric lighting) was built to serve as a chip storage area. It was built about 2 km from the two boilers that it supplied. A front-end loader loaded chips onto a shuttle truck that supplied the chips to the boiler. This system was more expensive because of the cost of building the storage area and the use of the second truck.

Costs

In the State of Maine, the 1988 price paid for whole-tree chips delivered to co-generation-type boiler installations from "large scale" chipping operations was about U.S. $17.00 per green (short) ton. The average haul distance was about 30 km; the maximum haul was 40 or 50 km. According to Mike Cyr of Marketree Ltd., Winterport, Maine, the price paid in 1988 to chip producers has not increased during the last 4-5 years. Chipping operators have become more efficient. After adjusting for currency changes and metric tonnes this means a delivered price of about Canadian $23.00 per green tonne (this assumes 45% moisture content, green weight basis).

In Atlantic Canada, the price of whole-tree chips produced by "large-scale" operations (e.g., Morbark 22) is about the same as in Maine (Canadian $23.00 to $25.00) if the average haul distance is similar (30 km). Most of the

small/medium chip producers visited by FERIC personnel reported that they received $28.00 to $30.00 per green tonne (avg. M.C. 45%, green weight basis). Two small producers reported prices of $33.00 per green tonne; two others, $35.00. One may conclude that small/medium chip producers have higher production costs than large scale producers. However, most small/medium producers were limited by small (limited) markets and constraints on trucking and chip dumping. They would have liked to produce more chips. Lower costs per tonne are possible on small/medium operations with higher chipper utilization.

Conclusions

Fuelwood chipping should normally be part of an integrated logging operation (integrated in the sense that a variety of products such as sawlogs, pulpwood or pulpchips are produced, as well as fuelchips). These products usually have a higher value than fuelwood chips. Fuelchip production can also compliment other types of business such as landclearing, site preparation or cutting road right-of-way. Fuelchip producers should be versatile and should avoid being overly dependent on one product/one market.

There are many aspects of small/medium fuelwood chipping operations that can be improved. As demand for fuelchips grows, existing loggers having good track records with mechanized logging should be encouraged to expand into

chipping operation (rather than persons with little or no logging experience). This policy has worked well in Maine.

Costs of fuelwood chips can be reduced by increasing chipper utilization since some chippers are used only one or two hours per day. At the biomass burning facility there should be enough space to back up a 40' van (having a moving floor dumping action). Also, the problem of long slivers should be resolved before chipping begins.

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FUEL HANDLING SYSTEMS FOR WOOD-FIRED HEATING PLANTS

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ADI Ltd.

Introduction

The focus of this presentation is the design and performance of wood handling systems in use in institutional heating plants in the Province of New Brunswick.

Seven plants have been selected for examination, and in the course of this discussion, we will examine the experience at each of these sites.

In general, the auger or screw conveyor is the most popular choice for transport of wood fuel over the relatively short distances involved in most of these plants. All of the plants studied use a screw type stoker to feed fuel to the furnace area.

All but one of these plants uses the reciprocating hydraulic scraper system for reclaim of wood fuel from the storage bin area.

The Hotel Dieu Hospital plant incorporates a "barn cleaner" conveyor, or a double-trough drag chain as it might be more formally named.

The UNB plant, as the largest of the group, incorporates drag chain conveyors, screw metering conveyors, a belt conveyor and a chain flail silo reclaim system, all of which will be discussed in the following sections.

Wood Handling System Performance

General

Table 1 provides basic plant data and estimated wood handling system maintenance costs for each of the seven plants considered. Table 2 presents a summary of features and design considerations for each type of conveyor for future applications

Hotel Dieu Hospital - Chatham, N.B.

Patz Conveyor

This plant is unique in New Brunswick in that it uses the "Patz" double-trough chain conveyor. Its advantage over conventional screw conveyors is that it is very low in power consumption, and it is able to turn both in the horizontal plane and the vertical plane. Thus, a single Patz conveyor can replace two or more screw conveyors and eliminates the necessity for a transition pit in the floor of the plant.

Several problems with the "Patz" were encountered in the initial start-up period of this plant. All of these have been addressed, and this conveyor is presently performing to the satisfaction of the owner.

Initially, the conveyor was equipped with a relatively light cold formed rod knuckle chain. This violated the first rule of wood handling conveyor design which states that all components must be brutally strong. A forged steel chain was retrofitted soon after start-up.

Problems with the horizontal and vertical bend details were also experienced in the early days of plant operation. The original mechanisms were incapable of dealing with the difficult nature of hog fuel and were prone to jamming.

These problems were aggravated by overloading of the conveyor by the hydraulic bin system.

The sloped section of the conveyor is incapable of transporting as much material as the flat section due to the nature of drag chain conveyors (as slope increases, capacity decreases). Therefore, it was essential to limit the quantity of material on the incoming flat section to that which could be handled on the sloped section. Otherwise, a buildup of material occurred at the transition point causing the chain to jam.

The solution to the overfeed problem was the installation of a "shear" gate over the conveyor trough where it leaves the loading area in front of the bin. This scalping gate is arranged at an angle to the carrying flights of the conveyor so that there is a small area of material pressure between the gate and the flight so the excess material is sheared off gently, much as a pair of scissors cuts paper.

The gate is equipped with a proximity sensor which cuts off the hydraulic withdrawal system for as long as there is material piled up behind the scalp gate.

The effect of this system is to periodically clean the Patz chain trough entirely, allowing any backlog of material to be cleared away, while at the same time limiting the maximum feed rate of the system.

The hold-downs for the carry and return sections of chain were converted to a variation of the well-known "star" roller commonly used to prevent fouling of belt conveyors. These star sprockets are able to hold the chain in position without jamming, even in the presence of large quantities of wood fuel.

The third modification was the redesign of the return bend support bearings on the horizontal plane bend. Problems were experienced here with fouling and jamming. A simple long-radius bend was installed using a length of ordinary roller chain as a bearing. This has effectively eliminated the previous problems.

The "Patz" conveyor, as modified, is not substantially less expensive than equivalent screw conveyors. However, it does simplify the overall installation and is a very energy efficient design. The elimination of one or more transitions between conveyors and the elimination of access pits in the floor offer good reliability and lower installed costs.

Hydraulic Scraper System

Like all such systems, the Hotel Dieu bin reclaim system has required maintenance of hydraulic seals, filters and cylinders over the years.

Problems arise from the relatively quick reversal of travel on the cylinders caused by quick acting solenoid values. Stress on the hydraulic system can be reduced through the use of pilot operated directional values designed for slow transition from forward to reverse direction.

Reclaim reliability has been good with no wear or repair costs for the scrapers themselves.

Screw Stoker

The screw stoker is a very simple design consisting of an auger supported only at the drive end, lying in a tube which terminates in a rectangular chamber or retort recessed into the grate. The screw forces wood into the retort, from which it escapes upwards into the combustion cell.

Very high pressures can occur in the retort area, with the result that the stoker screw is subject to considerable wear in the area just before the discharge point. As the screw wears, pressure in the area tends to increase because the carrying capacity is reduced in that local area, causing more fuel to be carried into the tube than can be carried out.

The phenomenon causes accelerated wear and overloading of the mechanical drive.

In normal service, this screw must be removed to repair worn surfaces approximately once per year.

The original stoker screw was a two-piece installation. This was found to be unworkable because of the tendency of the coupling bolts to break.

The cause of this breakage was fatigue due to stress concentration at the coupling bolts. The present stoker screw is a one-piece design which eliminates this problem. A recommendation for future improvement to this design would be the oversizing of the screw flights at the retort to compensate for wear. It is felt that this would allow longer intervals between screw rebuilds.

Chaleur Hospital - Bathurst, N.B.

Screw Conveyors

This plant uses screw conveyors throughout the fuel handling system. Initial problems were experienced with jamming at the transition points due to mismatching of feed rates. It is evident that the last conveyor in a series must operate at a capacity equal to or greater than the capacity of preceding conveyors so that a jam will not occur.

In practise, this means that for a group of conveyors, each subsequent unit must have a capacity significantly greater than the feed conveyor or trouble can be expected. After the operating speed of the feed conveyor was adjusted, minimal feed problems have been experienced with this system.

Hydraulic Bin Reclaim

The reclaim system generally works very well, but the usual hydraulic maintenance problems have been experienced. Seal failures and hose failures are due primarily to shock loads on reversal of cylinder direction. Breakage of scraper

hold-down clips has occurred on one occasion which resulted in scraper damage. This could have been caused by poor welding at the time of installation and is not a common occurrence.

Stoker

The screw stoker is subject to wear in the retort area. This unit has been modified to incorporate a greasable bearing on the retort end of the shaft which give smoother operation and longer service between overhauls. Overall performance is considered good.

Charlotte County Hospital

Screw Conveyor

This plant uses a single 9" screw to collect fuel from the bin discharge area and transport it to the screw stoker. The layout is simple, and this screw has not caused many problems.

This has been the only scraper bottom bin reclaim system in the group under consideration that has given significant trouble in the reclaim of wood fuel, showing a disturbing tendency to "rat hole" or "bridge", particularly during very cold weather when freezing is likely to be a factor. Solutions to the problem will centre around modification of the scrapers to provide better coverage of the bin bottom and vertical flights to assist in breaking arches.

Screw Stoker

The original stoker has been replaced with a more rugged unit which has provided satisfactory service with minimal maintenance.

University of New Brunswick

Chain Flail Bin Reclaim

A unique feature of the UNB plant is its two 60-foot silos with a 15 hp chain flail reclaim device installed in each. This system consists of a steel post extending upwards some 14 feet into the 30-foot diameter silo with a number of heavy chains attached at intervals along the length of the post with the longest chains at the top. At the end of each chain is a fist sized "claw" which flails at the wood fuel and drives it downward to the base of the pole and through an outlet to a surge hopper.

Advantages of this system include its simplicity, ruggedness, and its low power consumption.

Disadvantages include the cone shaped dead storage space inherent with the design. In addition, the chain flail is sensitive to extreme moisture content and will tend to jam when the wood is extremely wet and "packy". However, such jams can usually be cleared manually in a few minutes. A reversing starter was fitted to the flail drive to allow for momentary reversing to help free a jam.

A third problem can arise after several weeks or months of operation when the chains can become entangled and lose their effectiveness. This has not been a serious problem, but it is planned to stiffen the chains by threading a length of wire rope through the links. This modification should be sufficient to overcome the problem of tangling.

Metering Screw Conveyors

The silo surge bins are unloaded by short screw conveyors driven by variable speed DC motors. These serve as fuel feed control for the boiler. The screws are subject to some wear and have been replaced once in four years of operations (approximately 70,000 tons throughput). These units were initially underpowered at 2 horsepower and have subsequently been fitted with 5 horsepower drives which have performed well.

Drag Chain Conveyors

The drag chain conveyors fitted with hardwood flights are a good choice for moderate distances. They are very clean in operation since the conveyor can be totally enclosed.

Problems were initially encountered with wood packing between the sprocket and chain and causing excessive wear on both parts. This was corrected by fitting a rubber mat over the roller chain in the area of the loading chute so material is deflected off to the sides.

Belt Conveyer

The belt conveyor is ideally suited for long runs and high capacities. At UNB, the belt conveyor is relatively short and was used primarily to provide an opportunity to remove tramp iron from fuel through the use of a magnet, and also to install an in line weightmeter to measure fuel flow rates.

The primary disadvantage of the belt is primarily the housekeeping problem associated with the dustering that occurs near the discharge end particularly, but all along the underside of the belt as well. Small particles of wet dust adhere to the belt and then drop off during the return run.

Screw Stoker

The screw stoker at the UNB plant is similar in some respects to the smaller units described previously but differs in that the screw is supported on both ends by bearings, and the discharge end bearing is actually on the outside of the furnace. The screw discharges material into the retort, and reverse flights are used at the opposite end of the retort to prevent escape of fuel in that direction. The shaft in the retort area is equipped with rectangular paddles which assist in moving the fuel upwards to the grate.

Like the smaller units, this stoker is subject to extreme pressure and wear in the retort area. The screw must be removed and rebuilt every six to eight months.

Virtually all of the wear is in the last pitch of the screw before the retort and on the retort paddles themselves.

A motor ammeter was installed on the operator's console at the design stage to monitor the load on the stoker screw motor. This has proved to be a valuable early warning device, since it indicates the increasing mechanical load which accompanies screw wear.

Hugh John Flemming Forestry Complex

Scraper Bottom Bin

This plant is supplied with chip fuel made from silvicultural thinnings and slab wood from the training sawmill. The fuel is well sized and quite dry in comparison to the hog fuel used at other plants. As a result, there have been very few problems associated with wood handling at this plant.

The hydraulic system has required routine changing of fluid and filters, and has shown evidence of stress from rapid pressure reversal in the form of leaking seals.

Screw Conveyors

The only problems in wood handling have related to the transition between the horizontal and inclined screw at the discharge point of the bin. A photocell control is used to stop the outfeed of the bin when the discharge pit is nearly full. This control has failed on occasion, causing an overfeed problem. Most other plants avoid problems like this by ensuring that the feed rate to the inclined screw does not exceed its capacity. A closed transition can be used, and the control device is unnecessary.

Screw Stoker

This stoker has worked very well during the two years it has been in service

Victoria Health Centre

Scraper Bin

This bin was constructed from part of an old coal bunker which limited the depth of the floor, and grading considerations limited the overall depth available for fitting. As a result, the bin is shallower and has a larger floor area than would be ideal.

To get some additional storage, the floor of the bin was sloped down from the discharge end, which means the fuel must travel uphill to the collector screw. This has proven to be of minimal benefit, since it is difficult to withdraw wood from the back of the bin once the material level is down to the floor at the front end.

Screw Conveyors

The screw conveyors have worked well and have required minimal maintenance. The long, sloping conveyor has worn out two thrust bearings, indicating that a heavier bearing may be necessary.

Jams do occur occasionally due to oversize material, but the system is interlocked by means of switches on the trap doors provided at the discharge point of each conveyor. Lifting of the trap door my material pressure from the jam causes all conveyors to stop and an alarm to sound.

Screw Stoker

This stoker is quite similar to the unit at the Hotel Dieu plant and has experienced similar problems.

Madawaska Regional Correction Centre

Scraper Bin

This bin is handling primarily hardwood sawdust and chips and has worked very well since its installation. Hydraulic maintenance is minimal, but the system does receive attention.

Screw Conveyors

The layout of the screw conveyors is very similar to that at HJFFC, and the same comments apply.

It was found necessary to rebuild these screws shortly after start-up to install heavier flights and more substantial welds. The original screws were not heavy enough, and the flights were torn off the shaft due to foreign objects in the fuel stream. Since the rebuild, any similar incident has not caused any equipment damage.

Screw Stoker

No significant maintenance has been required. The load on this plant is relatively light, so the wear rate could be expected to be very slow with respect to all of the other plants examined.

Conclusions

General

Based on the plants examined, some general conclusions can be drawn about the selection, design and maintenance of conveying systems for wood-burning boiler plants.

A general requirement for any wood handling equipment is very rugged construction. Flimsy, light duty components will fail when the inevitable 2 x 4 is introduced to the fuel stream. Conveyors must be designed to protect themselves from damage due to oversize material and feed jams. Conveyors should be able to stall and trip the drive motor on overload without damage to conveyor drive.

Another general requirement is accessibility. Access doors must be provided at transfer points; all moving parts and bearings must be accessible for service and replacement. Working space must be adequate around all equipment.

Screw Conveyors

Screws are a good choice for short, straight runs. Twenty or twenty-five feet is the practical limit for a single screw without hanger bearings, and these devices are not recommended for wood conveyors. Nine inches would be a minimum size for a small plant, and twelve inches is preferable. Routine maintenance consists only of greasing bearings occasionally, changing gearbox oil, and servicing belt drives as required.

Patz Conveyor

The "barn cleaner" conveyor is very low in power consumption and can be made to work well on wood fuel applications. It should be considered where distances are moderately long and several screws might be necessary as an alternative.

Drag Chain Conveyor

The drag chain is a good choice for a long, straight run where cleanliness is important. Power consumption is moderate, and operation is quiet.

Belt Conveyor

The belt conveyor is most suitable for use outdoors where its inherent dirtiness is not a consideration.

Chain Flail Reclaim Mechanism

The chain flail is a rugged, simple reclaim mechanism for use in a circular silo. It is very low in power consumption and does not require a great deal of maintenance. On very wet fuels, it can be subject to jamming.

This is the most common type of fuel storage system and generally works very well. Some problems have been experienced with bridging at the Charlotte County Hospital plant, but this is generally not a problem elsewhere.

Future systems should use an improved hydraulic system incorporating smooth pressure release and reversal. This would certainly reduce the necessary maintenance on hydraulic systems by prolonging component life.

Future Improvements

It is natural that plant operators and designers will experiment and improve the performance of their plants as they gain experience with these systems in the long term. In this discussion, we have touched on a few weak points in existing plants and identified some steps that could potentially eliminate them or reduce their effects.

	HOTEL DIEU	CHALEUR HOSPITAL	CHARLOTTE CO. HOSPITAL	UNB	HJFFC	VHC	MADAWASKA
Boiler, h.p.	125 psi 100	125 psi 300	125 psi 60	250 psi 1200	15 psi 200	125 psi 100	HOT WATER 50
Annual Production BTU x 10E9	16.5	42.6	8.9	205.4	18	24.4	2.6
Typical Annual Fuel Consumption (tons)	3000	9900	2000	35000	2140	3600	400
Type of Fuel	HOG	HOG	HOG	HOG	CHIPS	HOG	SAWDUST, CHIPS
Fuel Delivery Rate tons/hr	0.64	1.95	.38	7.7	1.26	0.64	.32
Approx. Fuel Storage Capacity (cu. ft)	3900	6800	2000	38000	5000	2500	2200
Bin Reclaim	5 h.p. 5 scrapes	20 h.p. scrapes	5 h.p. scrapes	15 h.p. Chain Flail	15 h.p. 3 scrapes	15 h.p. 6 scrapes	5 h.p. 3 scrapes
Conveyor #1	2 h.p. PATZ	5 h.p. Screw	3 h.p. Screw	5 h.p. Screw	3 h.p. Screw	3 h.p. Screw	2 h.p. Screw
Conveyor #2	NA	5 h.p. Screw	NA	Drag Chain	3 h.p. Screw	3 h.p. Screw	NA
Conveyor #3	NA	5 h.p. Screw	NA	7.5 h.p. Drag, Chain	NA	3 h.p. Screw	NA
Conveyor #4	NA	NA	NA	3 h.p. Belt	NA	NA	NA
Stoker	5 h.p. Screw	7.5 h.p. Screw	2 h.p. Screw	30 h.p. Screw	3 h.p. Screw	5 h.p. Screw	3 h.p. Screw
Total Conveyor, h.p.	12	42.5	10	61.5	24	27	10
Estimated Annual Maintenance Cost	1500	2000	1000	10000	2000	1500	500

TABLE 1
PLANT DATA

	SCREW CONVEYOR	DRAG CHAIN	PATZ CONVEYOR	BELT CONVEYOR	SCRAPER BOTTOM BIN	CHAIN FLAIL BIN	SCREW STOKER
ADVANTAGES	SIMPLE, ONE PIECE, USEFUL TO METER FLOW, CLEAN	CLEAN, HIGH CAPACITY	LOW POWER, CAN BEND IN 2 PLANES	NON-MAGNETIC HIGH SPEED CAN BE VERY LONG	VERY RELIABLE PERFORMANCE FULL LIVE BOTTOM WITHDRAWL CAPABILITY	LOW COST, SIMPLE, LARGE CAPACITY	LOW COST, UNDERFED FIRE GOOD COMBUSTION
DISADVANTAGES	MUST BE QUITE SHORT	SUBJECT TO DAMAGE BY FOREIGN OBJECTS	SUBJECT TO DAMAGE BY FOREIGN OBJECTS	DIRTY, MANY IDLERS TO MAINTAIN	EXPENSIVE PER UNIT VOLUME, REQUIRE HYDRAULIC SYSTEM	SUBJECT TO JAMMING ON DIFFICULT FUELS	HIGH WEAR
ROUTINE MAINTENANCE CONSUMABLES	GEAR OIL DRIVE BELT GREASE	GEAR OIL DRIVE BELT GREASE ADJUST CHAIN	GEAR OIL DRIVE BELT GREASE ADJUST TENSION	GEAR OIL DRIVE BELT GREASE ADJUST BELT CLEAN UP	HYDRAULIC OIL AND FILTERS	GEAR OIL DRIVE BELT GREASE	GEAR OIL DRIVE BELT GREASE
REPAIRS OCCASIONALLY NECESSARY	REPLACE BEARINGS	REPLACE DAMAGED FLIGHTS SHORTEN CHAIN	REPLACE DAMAGED FLIGHTS	ADJUST BELT TENSION	REPLACE HOSES REPLACE SEALS	REPLACE CLAWS UNTANGLE CHAINS	REBUILD SCREW AT RETORT AREA HARD FACING
SENSITIVITY TO OVERSIZE OR FOREIGN OBJECTS IN FUEL	HIGH	MEDIUM	LOW	LOW	LOW	LOW	HIGH
DESIGN CONSIDERATIONS	LARGE, HEAVY CONSTRUCTION KEEP RUNS SHORT	USE OVERSIZE CHAIN, SPROCKETS WOODEN FLIGHTS	HEAVY CHAIN SPECIAL BEND DETAILS		HYDRAULICS DESIGN NEEDS IMPROVEMENT	STIFFEN CHAINS PROVIDE FOR REVERSE JOGGING	OVERSIZE FLIGHTS AT RETORT TO RETARD WEAR EFFECT

TABLE 2
CHARACTERISTICS OF
WOOD HANDLING SYSTEMS

L I S T O F
P A R T I C I P A N T S

REGISTRATION

WOOD ENERGY SYMPOSIUM

October 25 - 26, 1988

NAME	AFFILIATION	ADDRESS	CITY	PROV.	POSTAL CODE
ABBOTT, Don	Research & Productivity Council	P.O. Box 20,000	Fredericton	NB	E3B 6C2
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BARTON, Harold	SNB Wood Co-op		Chipman,Queens Co.	NB	E0E 1C0
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BEATON, Bruce R.	Forest Extension Service, DNRE	Hugh John Flemming Forestry Centre	Fredericton	NB	E3B 5H1
BENTEAU, Steve (Press)	Daily Gleaner		Fredericton	NB	
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COOK, V. Brian	Energy, Mines & Resources Can.	Suite 503, 5151 George Street	Halifax	NS	B3J 1M5
CORBIN, David	Fraser Inc.		Plaster Rock	NB	
COREY, John	McCain Foods Ltd.	P.O. Box 97	Florenceville	NB	E0J 1K0
CORMIER, LeAndre	Georgetown Timber Ltd.	Boite 294	St-Antoine,	NB	E0A 2X0
CORMIER, William J.	W.J. Cormier Co. Ltd.	1025 Miramichi Ave.	Bathurst	NB	E2A 1X9
CROWDIS, Frank	North Inverness Forest Mgmt.Ltd.	P.O. Box 179	Port Hood	NS	B0E 2W0
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JENKINS, John	Fraser Inc.		Plaster Rock	NB	
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JONES, Stephen	Miramichi Pulp & Paper	P.O. Box 5040	Newcastle	NB	E1V 3N3
LaROCHE, Bob (75.00)	Dept. of Labour	P.O. Box 6000	Fredericton	NB	E3B 5H1
LEMIEUX, Gerard	Energy & Resources, Prov.of Quebec	200 semain Ste.-Foy	Quebec	PQ	G1R 4X7
LEVY, John	SNB Wood Co-op	P.O. Box 137	Sussex	NB	E0E 1P0
LISLE, Bruce R.	Mapleleaf Technologies Ltd.	R.R. #1, 103 Rudderham Rd.	N. Sydney	NS	B2A 3L7
LOSIER, M.B.	Natural Resources and Energy	P.O. Box 6000	Fredericton	NB	E3B 5H1
LOSIER, Michel	NB Power	P.O. Box 2000, 515 King St.	Fredericton	NB	E3B 4X1
LUND, Daniel		P.O. Box 1016	Sackville	NB	E0A 3C0
MACDONALD, J. Ian	N.B. Forest Products Comm.	Hugh John Flemming Forestry Centre	Fredericton	NB	E3B 5H1
MACEWEN, Garry	Natural Resources & Energy	P.O. Box 6000	Fredericton	NB	E3A 1N3
MACFARLANE, M. David	Timber Management Br., DNRE	Hugh John Flemming Forestry Centre	Fredericton	NB	E3B 5H1
MACLAGGAN, R.S.	Natural Resources & Energy	P.O. Box 6000	Fredericton	NB	E3B 5H1
MAGEE, Jeff	Sunbury Transport Ltd.	P.O. Box 905, P.S. "A"	Fredericton	NB	E3B 5B4
MARSHALL, John	Nova Scotia Research Foundation	Box 790	Dartmouth	NS	B2Y 3Z7
MARSHALL, John E.	Marshall Harvesting Ltd.	RR #4, Box #5	St. Stephen	NB	E3L 2Y2
MARSHALL, Willis	Municipality of Dist. of Digby		Digby	NS	B0V 1A0
MCCALLUM, Bruce		R.R. #4	Hunter River	PE	C0A 1N0
MCKENNA, Hon. Frank, Premier	Province of New Brunswick	P.O. Box 6000	Fredericton	NB	E3B 5H1
MCKNIGHT, Paul	PEI Energy & Forestry	P.O. Box 2000	Charlottetown	PI	C1A 7N8
MILLAR, Alan	Energy, Mines & Resources	835 Champlain St.	Dieppe	NB	E1A 1P6
MOODIE, R.L.	Consultant	11 Rutherford Cres.	Kanata	ON	K2K 1N1
MORAN, Frank, Bd.Directors	P.E.I. Energy Corporation	P.O. Box 2000	Charlottetown	PI	C1A 7N8
MURPHY, Linda	Neill & Gunter Ltd.	P.O. Box 713	Fredericton	NB	E3B 5B4
MURRAY, Dave	Crowfield Associates Ltd.	Bungalow Place	Charlottetown	PI	C1A 1YS
NELSON, Barry	Timber Management Br., DNRE	Hugh John Flemming Forestry Centre	Fredericton	NB	E3B 5H1
OWENS, E.T.	Natural Resources and Energy	P.O. Box 6000	Fredericton	NB	E3B 5H1
PAASCHE, Per E.	Bio Engineering Inst.	Box 4400, UNB	Fredericton	NB	E3B 5A3
PARKER, Allan	Nova Scotia Mines & Energy	P.O. Box 1087	Halifax	NS	B3J 2X1
PIERCY, J.	ADI Limited	P.O. Box 44	Fredericton	NB	E3B 4Y2
PIKE, J.B.	Ashley Colter (1961) Ltd.	P.O. Box 2100	Fredericton	NB	E3B 4Y6
REES, Maurice	Atlantic Forestry Journal	5426 Portland Place	Halifax	NS	B3K 1A1
REINSCH, A.E.	Canadian Energy Research Inst.	3512 -33 Street, N.W.	Calgary	AB	T2L 2A6
RICHARD, J.	Natural Resources and Energy	P.O. Box 6000	Fredericton	NB	E3B 5H1
ROBICHAUD, M.	Province of New Brunswick	P.O. Box 6000	Fredericton	NB	E3B 5H1
ROBLEE, John, Chairman	Nova Scotia Group Venture Assoc.	R.R. #?	Oxford	NS	B0M 1P0

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ROSEN, Bertil	Energy Systems KMW Inc.	150 White Oak Rd.	London	ON	N6E 3A1
SEELEY, George	Department of Supply & Services	P.O. Box 6000	Fredericton	NB	E3B 5H1
SCHNEIDER, Dr. Marc	Faculty of Forestry, U.N.B.	P.O. Box 4400	Fredericton	NB	E3B 5A3
SHAW, Randy	Fort Fairfield Energy Venture	P.O. Box 492	Fort Fairfield	ME	04742
SLEEP, L.	Natural Resources and Energy	P.O. Box 6000	Fredericton	NB	E3B 5H1
SMITH, Scott	Bowater Mersey Paper Company	Box 1150	Liverpool	NS	B0T 1K0
SOOLEY, Kevin	Babcock & Wilcox Canada	479 Rothesay Ave.	Saint John	NB	E2J 2C6
SOUCY, L.	Natural Resources and Energy	P.O. Box 6000	Fredericton	NB	E3B 5H1
SOULARD, Raymond	Signal-Sherman Energy Co.	P.O. Box 189	Sherman Sta.	ME	04777
STAPLES, George	Frobisher Industries Ltd.	Young's Cove Road		NB	E0E 1S0
STRANGE, Dr. D.L.P.	Renewable Energy Br., EMR	460 O'Connor St.	Ottawa	ON	K1S 5H3
STUART, Dr. W.B.	Virginia Polytechnic Inst.	228 Cheatham Hall	Blacksburg	VA	24061-0324
STUART, John	Forest Service - Region 2, DNRE	80 Pleasant Street	Newcastle	NB	E1V 1X7
TORUNSKI, Wilf	J.D. Irving Ltd.	P.O. Box 5777/300 Union St.	Saint John	NB	
TOWNSEND, Bradford	Acadia University		Wolfville	NS	B0P 1X0
THERIAULT, Adrian	C.P. 234		Paquetville	NB	E0B 2B0
VAN RAALTE, Gerrit D.	Canada Forestry Service	P.O. Box 4000	Fredericton	NB	E3B 5P7
WALICKI, Tom	East-West Forestry Associates	17 Lewis Road	New Britain	CT	06053
WALKER, Bryan, Dep. Minister	Natural Resources and Energy	P.O. Box 6000	Fredericton	NB	E3B 5H1
WALSH, George	Maritime Forest Ranger School	Hugh John Flemming Forestry Centre	Fredericton	NB	E3B 5H1
WILLIAMS, L.L.	Natural Resources and Energy	P.O. Box 6000	Fredericton	NB	E3B 5H1
YORK, Richard	Dept. Supply & Services	65 Brunswick St.(Victoria Health Cen.)	Fredericton	NB	

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